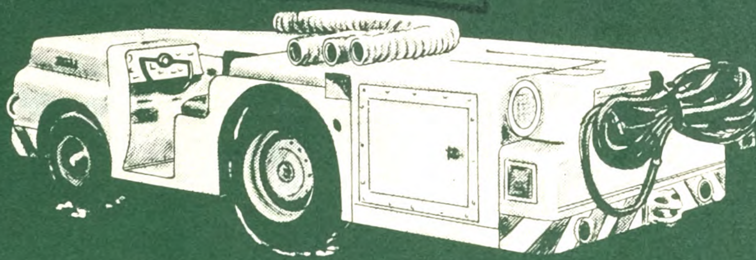

AVIATION

SUPPORT EQUIPMENT TECHNICIAN H 3 & 2

NAVAL TRAINING COMMAND

RATE TRAINING MANUAL NAVTRA 10316-A

PREFACE

This Rate Training Manual is one of a series of training manuals prepared for enlisted personnel of the Navy and Naval Reserve who are studying for advancement in the Aviation Support Equipment Technician rating. As indicated by the title, the manual is based on the professional qualifications for the rates ASH3 and ASH2, as set forth in the Manual of Qualifications for Advancement, NavPers 18068 (Series). A reading list, which includes USAFI texts recommended as study material for ASH personnel, is provided in the front of the manual.

Combined with the necessary practical experience, the completion of this manual will greatly assist the ASHAN and ASH3 in preparing for advancement. This manual should also be valuable as a review source for the more senior rates.

This training manual was prepared by the Navy Training Publications Center, NAS Memphis, Millington, Tennessee, for the Naval Training Command. Technical review of the manuscript was provided by personnel of the Aviation Support Equipment Technician School, NATTC, NAS Memphis, Millington, Tennessee, the Naval Examining Center, Great Lakes, Illinois, and the Naval Aviation Integrated Support Center, Patuxent River, Maryland. Technical assistance was also provided by the Naval Air Systems Command.

1972 Edition

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

CONTENTS

READING LIST

USAFI TEXTS

United States Armed Forces Institute (USAFI) courses for additional reading and study are available through your Educational Services Officer.* The following courses are recommended:

C 151 General Mathematics I
C 152 General Mathematics II
E 290 Physics I
F 741 Automotive Mechanics II

*"Members of the United States Armed Forces Reserve components, when on active duty, are eligible to enroll for USAFI courses, services, and materials if the orders calling them to active duty specify a period of 120 days or more."

CHAPTER 1
AVIATION SUPPORT EQUIPMENT TECHNICIAN H RATING

This Rate Training Manual is designed as a self-study test for use by those personnel of the Navy and Naval Reserve who are preparing to meet the professional (technical) qualifications for advancement to Petty Officer Third Class and Petty Officer Second Class in the rating of Aviation Support Equipment Technician H (Hydraulics and Structures). Minimum professional qualifications for advancement in all ratings are listed in the Manual of Qualifications for Advancement, NavPers 18068 (Series). The qualifications list which was used as a guide in the preparation of this manual was current in the 1971 revision of the Manual of Qualification for Advancement. Therefore, changes in the qualifications occurring after the 1971 revision may not be reflected in the information presented here. (The Manual of Qualifications for Advancement is discussed in more detail later in this chapter.)

ENLISTED RATING STRUCTURE

The present enlisted rating structure consists of general ratings and service ratings.

General ratings identify broad occupational fields of related duties and functions. Some general ratings include service ratings; others do not. Both Regular Navy and Naval Reserve personnel may hold general ratings.

Service ratings identify subdivisions or specialties within a general rating which require related patterns of aptitudes and qualifications, and which provide paths of advancement for career development. The general rating provides the primary means of identifying billet requirements and personnel qualifications; it is established or disestablished by the Secretary of the Navy; and it is provided a distinctive rating badge. The general rate is the pay grade level within the general rating. Although service ratings can exist at any petty officer level, they are most common at the PO3 and PO2 levels. Both Regular Navy and Naval Reserve personnel may hold service ratings.

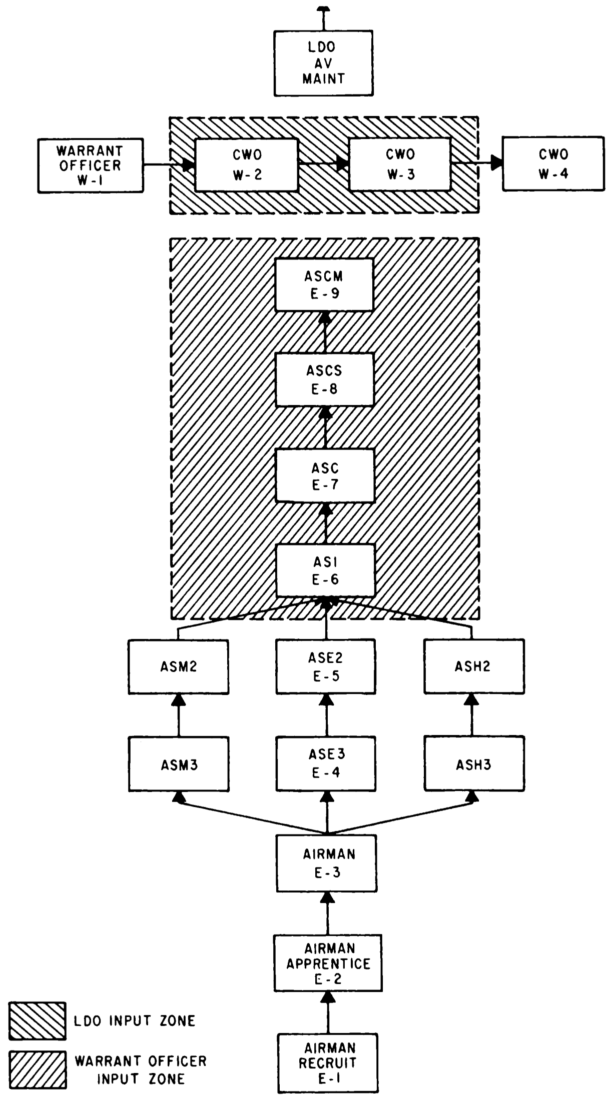
AVIATION SUPPORT EQUIPMENT TECHNICIAN (AS) RATING

The AS rating is divided into three service ratings at pay grades E-4 and E-5. The service ratings are ASE (Electrical), ASH (Hydraulics and Structures), and ASM (Mechanical). The general rating, AS, applies at pay grades E-6 through E-9.

Figure 1-1 illustrates all paths of advancement for an Airman Recruit to Master Chief Aviation Support Equipment Technician, Warrant Officer (W-4), or to Limited Duty Officer. Shaded areas indicate career stages where qualified enlisted personnel may advance to Warrant Officer (W-1) and selected Warrant Officers may advance to Limited Duty Officer. Personnel in enlisted rates and warrant ranks not in shaded areas may advance only as indicated by the lines.

NOTE: The above information concerning advancement to commissioned officer status applies only to the Limited Duty Officer program. It should be emphasized that there are other programs in which qualified enlisted personnel in pay grades E-5 and below may be promoted to commissioned officers. Consult Military Requirements for Petty Officer 3 & 2, NavPers 10056 (Series), and your local career counselor for current programs.

Personnel of the Aviation Support Equipment Technician H rating service, test, and perform Organizational and Intermediate level maintenance and repair of hydraulic and pneumatic systems and structural components of ground support equipment and maintain hydraulic test and service equipment, air compressors, jacks, workstands, and associated equipment. In performing these duties, the ASH welds, brazes, solders, cuts, shapes, and patches metal; performs body and fender metal work and painting of ground support equipment; adjusts and repairs brake systems; inspects and replaces tires and tubes; operates hydraulic test stands;



AS.1

Figure 1-1.—Paths of advancement.

and performs maintenance inspections of ground support equipment.

The ASH3 and ASH2 are usually assigned to activities that perform Intermediate level maintenance. Billets exist on all carriers from the smallest to the largest. ASH personnel assigned aboard carriers are usually attached to the Aircraft Intermediate Maintenance Department (AIMD).

Many interesting overseas shore billets exist for the ASH. If married, some Third Class and all Second Class Petty Officers may qualify to bring their dependents to these overseas locations at government expense. Shorter duty tours usually prevail at a few overseas stations where dependents are not allowed or choose not to go.

Between sea tours, the ASH Third or Second Class may be assigned to one of the many naval air stations along the gulf coast, east coast, and west coast. In addition, the Naval Air Training Command has a few naval air stations located inland where ASH personnel may be assigned. ASH personnel assigned to any one of these air stations will usually be attached to the Aviation Intermediate Maintenance Department (AIMD).

Having been in pay grade E-3 or E-4 for some time, it should be obvious that more leadership is required of the higher rates. This not only requires superior knowledge but also the ability to handle personnel. This ability increases in importance with advancement through the various rates as a Petty Officer.

In General Order No. 21, the Secretary of the Navy outlined some of the most important aspects of naval leadership. By naval leadership is meant the art of accomplishing the Navy's mission through people. It is the sum of those qualities of intellect, of human understanding, and of moral character that enable a man to inspire and manage a group of people successfully. Effective leadership, therefore, is based on personal example, good management practices, and moral responsibility. The term leadership includes all three of these elements.

The current Navy Leadership Program is designed to keep the spirit of General Order No. 21 ever before all naval personnel. If the threefold objective is carried out effectively in every command, the program will make each petty officer a better leader of men in his present billet and in future assignments. As the petty officer advances up the ladder of leadership, more and more of his worth to the Navy is judged on the basis of the amount of efficient work he obtains from his subordinates rather than how much of the actual work he does himself.

For information on the practical application of leadership and supervision, study Military Requirements for Petty Officer 3 & 2, NavPers 10056 (Series).

ADVANCEMENT

Some of the rewards of advancement are easy to see. You get more pay. Your job

assignments become more interesting and more challenging. You are regarded with greater respect by officers and enlisted personnel. You enjoy the satisfaction of getting ahead in your chosen Navy career.

The advantages of advancement are not yours alone. The Navy also profits. Highly trained personnel are essential to the functioning of the Navy. By advancement, you increase your value to the Navy in two ways: First, you become more valuable as a technical specialist in your own rating; and second, you become more valuable as a person who can train others, and thus make far-reaching contributions to the entire Navy.

HOW TO QUALIFY FOR ADVANCEMENT

What must you do to qualify for advancement? The requirements may change from time to time, but usually you must:

1. Have a certain amount of time in your present grade.
2. Complete the required Rate Training Manuals by either demonstrating a knowledge of the material in the manual by passing a locally prepared and administered test, or by passing the Enlisted Correspondence Course based on the Rate Training Manual.
3. Demonstrate your ability to perform all the practical requirements for advancement by completing the Record of Practical Factors, NavPers 1414/1.
4. Be recommended by your commanding officer, after the petty officers and officers supervising your work have indicated that they consider you capable of performing the duties of the next higher rate.
5. Successfully complete the applicable military/leadership examination which is required prior to participating in the advancement (professional) examination.

Some of these general requirements may be modified in certain ways. Figure 1-2 gives a more detailed view of the requirements for advancement of active duty personnel; figure 1-3 gives this information for inactive duty personnel.

BuPers Notice 1418 provides information on the scheduling of Navy-wide examinations for advancement to petty officer third class through chief petty officer.

Personnel preparing for advancement should check this notice closely since it is also utilized for the purpose of providing information relating to changes in the requirements for advancement for a specific series of tests.

Advancement is not automatic. After you have met all the requirements, you are eligible for advancement. You will actually be advanced only if you meet all the requirements (including making a high enough score on the written examination) and if quotas permit.

HOW TO PREPARE FOR ADVANCEMENT

What must you do to prepare for advancement? You must study the qualifications for advancement, work on the practical factors, study the required Rate Training Manuals, and study other material that is required. You will need to be familiar with the following:

1. Manual of Qualifications for Advancement, NavPers 18068 (Series).
2. Record of Practical Factors, NavPers 1414/1.
3. Bibliography for Advancement Study, NavTra 10052 (Series).
4. Applicable Rate Training Manuals and their companion Enlisted Correspondence Courses.
5. Examinations for advancement.

Collectively, these documents make up an integrated training package tied together by the qualifications. The following paragraphs describe these materials and give some information on how each one is related to the others.

"Quals" Manual

The Manual of Qualifications for Advancement, NavPers 18068 (Series), gives the minimum requirements for advancement. This manual is usually called the "Quals" Manual, and the qualifications themselves are often called "quals." The qualifications are of two general types: military requirements, and professional (or technical) qualifications.

Military requirements apply to all ratings rather than to any one particular rating. Military requirements for advancement to third class and second class petty officer rates deal with military conduct, naval organization, military justice, security, watch standing, and other subjects which are required of petty officers in all other ratings.

Professional qualifications are technical or professional requirements that are directly related to the work of each rating.

REQUIREMENTS*	E1 to E2	E2 to E3	#† E3 to E4	#E4 to E5	† E5 to E6	† E6 to E7	† E7 to E8	† E8 to E9
SERVICE	4 mos. service—or completion of	6 mos. as E-2.	6 mos. as E-3	12 mos. as E-4	24 mos. as E-5.	36 mos. as E-6. 8 years total enlisted service.	36 mos as E-7. 8 of 11 years total service must be enlisted.	24 mos. as E-8. 10 of 13 years total service must be enlisted.
SCHOOL	Recruit Training.		Class A for PR3, DT3, PT3, AME 3, HM 3, PN 3, FTB 3, MT 3,			Class B for AGC MUC, MNC. ††		
PRACTICAL FACTORS	Locally prepared check-offs.	Record of Practical Factors, NavPers 1414/1, must be completed for E-3 and all PO advancements.						
PERFORMANCE TEST			Specified ratings must complete applicable performance tests before taking examinations.					
ENLISTED PERFORMANCE EVALUATION	As used by CO when approving advancement.		Counts toward performance factor credit in advancement multiple.					
EXAMINATIONS**	Locally prepared tests.	See below.	Navy-wide examinations required for all PO advancements.				Navy-wide, selection board.	
RATE TRAINING MANUAL (INCLUDING MILITARY REQUIREMENTS)		Required for E-3 and all PO advancements unless waived because of school completion, but need not be repeated if identical course has already been completed. See NavPers 10052 (current edition).					Correspondence courses and recommended reading. See NavPers 10052 (current edition).	
AUTHORIZATION	Commanding Officer		Naval Examining Center					

* All advancements require commanding officer's recommendation.
† 1 year obligated service required for E-5 and E-6; 2 years for E-7, E-8 and E-9.
\# Military leadership exam required for E-4 and E-5.
** For E-2 to E-3, NAVEXAMCEN exams or locally prepared tests may be used.
†† Waived for qualified EOD personnel.

Figure 1-2.—Active duty advancement requirements.

REQUIREMENTS *	E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7	E8	E9
TOTAL TIME IN GRADE	4 mos.	6 mos.	6 mos.	12 mos.	24 mos.	36 mos. with total 8 yrs service	36 mos. with total 11 yrs service	24 mos. with total 13 yrs service
TOTAL TRAINING DUTY IN GRADE †	14 days	14 days	14 days	14 days	28 days	42 days	42 days	28 days
PERFORMANCE TESTS			Specified ratings must complete applicable performance tests before taking examination.					
DRILL PARTICIPATION	Satisfactory participation as a member of a drill unit in accordance with BUPERSINST 5400.42 series.							
PRACTICAL FACTORS (INCLUDING MILITARY REQUIREMENTS)	Record of Practical Factors, NavPers 1414/1, must be completed for all advancements.							
RATE TRAINING MANUAL (INCLUDING MILITARY REQUIREMENTS)	Completion of applicable course or courses must be entered in service record.							
EXAMINATION	Standard Exam		Standard Exam required for all PO Advancements. Also pass Military Leadership Exam for E-4 and E-5.				Standard Exam, Selection Board.	
AUTHORIZATION	Commanding Officer		Naval Examining Center					

* Recommendation by commanding officer required for all advancements.

† Active duty periods may be substituted for training duty.

Figure 1-3.—Inactive duty advancement requirements.

Both the military requirements and the professional qualifications are divided into subject matter groups; then, within each subject matter group, they are divided into practical factors and knowledge factors. Practical factors are things you must be able to DO. Knowledge factors are things you must KNOW in order to perform the duties of your rate.

The qualifications for advancement and a bibliography of study materials are available in your educational services office. Study these qualifications and the military requirements carefully. The written examination for advancement will contain questions relating to the knowledge factors and the knowledge aspects of the practical factors of both the military requirements and the professional qualifications. If you are working for advancement to second class, remember that you may be examined on third class qualifications as well as on second class qualifications.

It is essential that the "quals" reflect current requirements of fleet and shore operations, and that new fleetwide technical, operational, and procedural developments be included. For these reasons, the qualifications are continually under evaluation. Although there is an established schedule for revisions to the "quals" for each rating, urgent changes to the "quals" may be made at any time. These revisions are issued in the form of changes to the "Quals" Manual. Therefore, never trust any set of "quals" until you have checked the change number against an up-to-date copy of the "Quals" Manual. Be sure you have the latest revision.

Record of Practical Factors

Before you can take the Navy-wide examination for advancement, there must be an entry in your service record to show that you have qualified in the practical factors of both the military requirements and the professional qualifications. A special form known as the Record of Practical Factors, NavPers 1414/1 (plus the abbreviation of the appropriate rating), is used to keep a record of your practical factor qualifications. The form lists all practical factors, both military and professional. As you demonstrate your ability to perform each practical factor, appropriate entries are made in the DATE and INITIALS columns.

Changes are made periodically to the Manual of Qualifications for Advancement and revised forms of NavPers 1414/1 are provided when necessary. Extra space is allowed on the Record of Practical Factors for entering additional practical factors as they are published in changes. The Record of Practical Factors also provides space for recording demonstrated proficiency in skills which are within the general scope of the rate but which are not identified as minimum qualifications for advancement.

If you are transferred before you qualify in all practical factors, NavPers 1414/1 should be forwarded with your service record to your next duty station. You can save yourself a lot of trouble by making sure that this form is actually inserted in your service record before you are transferred. If the form is not in your service record, you will be required to start all over again and requalify in the practical factors which have already been checked off.

A second copy of the Record of Practical Factors should be made available to each man in pay grades E-2 through E-8 for his personal record and guidance.

The importance of NavPers 1414/1 cannot be overemphasized. It serves as a record to indicate to the petty officers and officers supervising your work that you have demonstrated proficiency in the performance of the indicated practical factors and is part of the criteria utilized by your commanding officer when he considers recommending you for advancement. In addition, the proficient demonstration of the applicable practical factors listed on this form can aid you in preparing for the examination for advancement. Remember that the knowledge aspects of the practical factors are covered in the examinations for advancement. Certain knowledge is required to demonstrate these practical factors and additional knowledge can be acquired during the demonstration. Knowledge factors pertain to that knowledge which is required to perform a certain job. In other words, the knowledge factors required for a certain rating depend upon the jobs (practical factors) that must be performed by personnel of that rating. Therefore, the knowledge required to proficiently demonstrate these practical factors will definitely aid you in preparing for the examination for advancement.

NavTra 10052

Bibliography for Advancement Study, NavTra 10052 (Series), is a very important publication for anyone preparing for advancement. This bibliography lists required and

recommended Rate Training Manuals and other reference material to be used by personnel working for advancement. NavTra 10052 is revised and issued once each year by the Naval Training Command. Each revised edition is identified by a letter following the NavTra number. When using this publication, be sure that you have the most recent edition.

If extensive changes in qualifications occur between the annual revisions of NavTra 10052, a supplementary list of study material may be issued in the form of a BuPers Notice. When you are preparing for advancement, check to see whether changes have been made in the qualifications. If changes have been made, see if a BuPers Notice has been issued to supplement NavTra 10052.

The required and recommended references are listed by rate level in NavTra 10052. If you are working for advancement to third class, study the material that is listed for third class. If you are working for advancement to second class, study the material that is listed for second class. Remember that you are also responsible for the references listed at the third class level.

In using NavTra 10052, you will notice that some Rate Training Manuals are marked with an asterisk (*). Any manual marked in this way is MANDATORY—that is, it must be completed at the indicated rate level before you are eligible to take the Navy-wide examination for advancement. Each mandatory manual may be completed by passing the appropriate enlisted correspondence course that is based on the mandatory training manual; passing locally prepared tests based on the information given in the training manual, or in some cases, successfully completing an appropriate Class A School.

Do not overlook the section of NavTra 10052 which lists the required and recommended references relating to the military standards/requirements for advancement. For example, all personnel must complete the Rate Training Manual, Military Requirements for Petty Officer 3 & 2, NavPers 10056 (Series), for the appropriate level before they can be eligible to advance.

The references in NavTra 10052 which are recommended, but not mandatory, should also be studied carefully. All references listed in NavTra 10052 may be used as source material for the written examinations at the appropriate rate levels.

Rate Training Manuals

There are two general types of Rate Training Manuals. Rating manuals (such as this one) are prepared for most enlisted rates, giving information that is directly related to the professional qualifications. Basic manuals give information that applies to more than one rate and rating. Basic Electricity, NavPers 10086 (Series), is an example of a basic manual, because many ratings use it for reference.

Rate Training Manuals are revised from time to time to keep them up to date technically. The revision of a Rate Training Manual is identified by a letter following the NavPers number. You can tell whether any particular copy of a Rate Training Manual is the latest edition by checking the NavPers number and the letter following this number in the most recent edition of List of Training Manuals and Correspondence Courses, NavTra 10061 (Series). (NavTra 10061 is actually a catalog that lists current training manuals and correspondence courses; you will find this catalog useful in planning your study program.)

Rate Training Manuals are designed to help you prepare for advancement. The following suggestions may help you to make the best use of this manual and other Navy training publications when you are preparing for advancement.

1. Study the military requirements and the professional qualifications for your rate before you study the training manual, and refer to the "quals" frequently as you study. Remember, you are studying the training manual in order to meet these "quals."

2. Set up a regular study plan. If possible, schedule your studying for a time of day when you will not have too many interruptions or distractions.

3. Before you begin to study any part of the training manual intensively, become familiar with the entire manual. Read the preface and the table of contents. Check through the index. Look at the appendixes. Thumb through the manual without any particular plan, looking at the illustrations and reading bits here and there as you see things that interest you.

4. Look at the training manual in more detail, to see how it is organized. Look at the table of contents again. Then, chapter by chapter, read the introduction, the headings, and the subheadings. This will give you a clear picture of the scope and content of the manual. As you look through the manual in this way, ask yourself

some questions: What do I need to learn about this? What do I already know about this? How is this information related to information given in other chapters? How is this information related to the qualifications for advancement?

5. When you have a general idea of what is in the training manual and how it is organized, fill in the details by intensive study. In each study period, try to cover a complete unit—it may be a chapter, a section of a chapter, or a subsection. If you know the subject well, or if the material is easy, you can cover quite a lot at one time. Difficult or unfamiliar material will require more study time.

6. In studying any one unit—chapter, section, or subsection—write down the questions that occur to you. Many people find it helpful to make a written outline of the unit as they study, or at least to write down the most important ideas.

7. As you study, relate the information in the training manual to the knowledge you already have. When you read about a process, a skill, or a situation, try to see how this information ties in with your own past experience.

8. When you have finished studying a unit, take time out to see what you have learned. Look back over your notes and questions. Maybe some of your questions have been answered, but perhaps you still have some that are not answered. Without referring to the training manual, write down the main ideas that you have learned from studying this unit. Do not quote the manual. If you cannot give these ideas in your own words, the chances are that you have not really mastered the information.

9. Use Enlisted Correspondence Courses whenever you can. The correspondence courses are based on Rate Training Manuals or on other appropriate texts. As mentioned before, completion of a mandatory Rate Training Manual can be accomplished by passing an Enlisted Correspondence Course based on the Rate Training Manual. You will probably find it helpful to take other correspondence courses, as well as those based on mandatory training manuals. Taking a correspondence course helps you to master the information given in the training manual, and also helps you see how much you have learned.

10. Think of your future as you study Rate Training Manuals. You are working for advancement to third class or second class right now, but someday you will be working toward higher rates. Anything extra that you can learn now will help you.

SOURCES OF INFORMATION

One of the most useful things you can learn about a subject is how to find out more about it. No single publication can give you all the information you need to perform the duties of your rating. You should learn where to look for accurate, authoritative, up-to-date information on all subjects related to the military requirements for advancement and the professional qualifications of your rating.

Some of the publications described in this manual are subject to change or revision from time to time—some at regular intervals, others as the need arises. When using any publication that is subject to change or revision, be sure that you have the latest edition. When using any publication that is kept current by means of changes, be sure you have a copy in which all official changes have been made. Studying canceled or obsolete information will not help you perform efficiently or to advance; it is likely to be a waste of time, and may even be seriously misleading.

The importance of basic Rate Training Manuals cannot be overemphasized. They provide fundamental information on the specific subject, which is not repeated in this manual. In many cases this information provides coverage on professional qualifications and, therefore, may be used as source material for written examinations. These manuals are referenced in appropriate places throughout this manual. A list of the basic manuals which are of particular importance to the ASH is presented as follows:

Basic Electricity, NavPers 10086-B.
Tools and Their Uses, NavPers 10085-B.
Basic Machines, NavPers 10624-A.
Fluid Power, NavPers 16193-B.
Blueprint Reading and Sketching, NavPers 10077-C.

In addition to coverage of military requirements, NavPers 10056-C, Military Requirements for Petty Officer 3 & 2, also provides coverage on professional qualifications pertaining to the Naval Aviation Maintenance Program.

You may find it useful to consult some of the Rate Training Manuals prepared for other Group IX (Aviation) ratings. This is especially important for personnel of a service rating such as the ASH. To advance to AS1, the ASH2 must have a thorough knowledge of the electrical and mechanical specialties. Therefore, reference to the manuals prepared for the ASE and ASM service rating could prove very beneficial.

CHAPTER 2
PUBLICATIONS

The primary purpose of technical publications is to aid the technician in accomplishing his work. They are designed for him and communicate information and directions to him in his own specific technical language. They are prepared by the manufacturer of specific equipment and by the Naval Air Systems Command or its field activities in accordance with specifications issued by NavAirSysCom. They set forth current, authoritative information concerned with material upkeep, check, test, repair, and operation in a manner to provide for optimum product performance. It is extremely important, and therefore mandatory, that all personnel responsible for the operation and maintenance of ground support equipment be thoroughly familiar with and use these publications and the information contained therein in the daily execution of their technical tasks. The time has long since passed when the technician or mechanic could properly perform his work without written technical aid or, at the most, after a "thumbing through" or a one-time reading of the related technical publication. Modern technology is a constantly changing thing and demands continuous reference to and use of the approved and provided ways and means of keeping technically current.

Although some technical publications of interest to the ASH are issued by other Naval Commands, such as Naval Facilities Engineering Command and the Naval Ordnance Systems Command, the majority are issued by the Naval Air Systems Command. The publications issued by NavAirSysCom are known as aeronautic publications and are grouped into two major classes or groups—those issued in the form of MANUALS, and those issued in the form of LETTER MATERIAL.

When a new item of equipment is accepted by the Navy, manuals necessary to insure its proper operation and upkeep are prepared and made available to all activities using and/or maintaining the equipment. Supplemental information and other directive type publications that must be issued from time to time are issued in the form of letter material. Both manual and letter type publications may, on occasion, be properly referred to as directives. Broadly speaking, any communication which initiates or governs action, conduct, or procedures is a directive. Another term commonly used to identify manual and letter type publications is technical data.

As emphasized throughout this manual, all personnel of the ASH rating must use applicable technical publications in the performance of their duties. This chapter is devoted primarily to the type of information contained in various technical publications relative to the operation, servicing, and maintenance of support equipment.

All aeronautic publications, both manual and letter type, are assigned a title and code number. When they are available for issue, all publications, except Instructions and Notices, are listed in the Naval Aeronautic Publications Index. One of the requirements for advancement to ASH2 is to be able to use the different parts of this Index to locate and identify publications relative to the maintenance of support equipment. The contents and use of the Naval Aeronautic Publications Index are discussed in the first part of this chapter.

NAVAL AERONAUTIC PUBLICATIONS INDEX

A complete Naval Aeronautic Publications Index consists of several individual publications, each of which serves a specific purpose. They are identified as follows:

Navy Stock List of Forms and Publications, NavSup Publication 2002, Section VIII, Parts C and D (commonly referred to as the Numerical Sequence List or Numerical Index).

Equipment Applicability List, NavAir 00-500A.

Aircraft Application List, NavAir 00-500B.

Directives Application List by Aircraft Configuration, NavAir 00-500C.

Letter Type Technical Directives Equipment and Subject Applicability List, NavAir 00-500D.

The content and purpose of each of these publications are discussed in the following paragraphs.

NUMERICAL INDEX

NavSup Publication 2002 is a 13-section index of all the forms and publications used throughout the Navy and stocked by the Naval Supply Systems Command. Section VIII of this Stock List contains Naval Air Systems Command publications. This section is made up of four parts—A, B, C, and D. Parts A and B pertain to ordnance publications. Part C and Part D make up one part of the Naval Aeronautic Publications Index. Part C is the numerical listing of manaul type aeronautic technical publications, and Part D is the numerical listing of letter type publications. These two parts—C and D—are referred to as the Numerical Sequence List or Numerical Index of the Naval Aeronautic Publications Index.

Part C (manual publications) is divided into subject matter groups, and all publications within a group are then listed in numerical order according to code number. For example, all manuals in the 00 series are listed first, then followed by the 01, 02, 03, etc., through the 51 series. The listing includes the publication code number, stock number, title, date of the latest issue or revision, security classification, and requisition restriction code. In addition, each publication is identified as a basic issue or as a change to the basic issue. A listing of the general subject groups is shown in table 2-1.

Part D of Section VIII of the Stock List (letter type directives) is further divided into a number of subsections. Most of these subsections pertain to aircraft and are listed as Airframe Bulletins and Changes, Powerplant Bulletins and Changes, Accessories Bulletins and Changes, etc. The subsection which is of most interest to the ASH is the support equipment section. This subsection contains a listing of all Support Equipment Bulletins and Changes. The Bulletins and Changes are listed by publication number, title, security classification, and date of issue.

A table of contents and a general alphabetical cross-reference listing are provided in each Part (C and D) of the Index. In addition, instructions for using the Index are provided in Part C. Included in these instructions are the methods for procuring aeronautic publications, the forms and procedures required for ordering publications, and explanations of certain codes used in the Index.

Table 2-1.—General subject classification numbers for manual type publications.

General	00
Aircraft	01
Powerplants (02A Reciprocating engines, 02B Jet engines, 02F Rocket engines)	02
Accessories	03
Hardware and Rubber Material	04
Instruments	05
Fuels, Lubricants, and Gases	06
Dopes and Paints	07
Electronics	08 & 16
Instructional Equipment and Training Aids	09 & 28
Photography	10
Aviation Armament	11
Fuel and Oil Handling Equipment	12
Parachute and Personal Survival Equipment	13
Hangars and Flying Field Equipment	14
Standard Preservation and Packaging Instructions	15
Machinery, Tool, and Test Equipment	17 & 18
Ground Servicing and Automotive Equipment	19
Descriptive Data Sheets for Aviation Support Equipment	20
Chemical Equipment	24 & 39
Meteorology	50
Ship Installations	51

The Numerical Index must be used to completely identify and, therefore, to order required publications. However, the other parts of the Index (discussed in the following paragraphs) must be used to determine what publications are available for a specific item of equipment and to check the applicability of publications to specific equipment.

When an applicable publication number is found in one of the other parts of the Naval Aeronautic Publications Index, it can be easily located in the Numerical Index. Here, it can be more completely identified as to title and nomenclature, stock number (for manual type publications), security classification, and any restrictions concerning the requisitioning of the publication. In addition, the date of the latest issue or revision of the publication is listed. This provides a means whereby the issue and/or revision dates of the publications on hand in an activity can be checked against the dates listed in the current issue and supplement (discussed later) of the Numerical Index, thus assuring that the publications are current. Also, the basic issue of a publication and each change to that publication are identified by different stock numbers and therefore may be requisitioned separately. However, a requisition for the basic issue automatically includes all current changes.

EQUIPMENT APPLICABILITY LIST

Basically, the Equipment Applicability List, NavAir 00-500A, is a cross-reference index listing of NavAir manual type publications according to model/type part number. Since this Index contains several thousand entries, one document would be very cumbersome to use. For this reason, this Index is divided into several volumes. At the time of this writing, there are seven volumes. Each of the first six volumes contains 400 pages and Volume 7 contains the remaining entries. With the exception of several small sections in the first part of Volume 1, the Equipment Applicability List is one continuous index of model/type part numbers listed in strict alphanumerical sequence. In addition to an Introduction, the other sections in the first part of Volume 1 pertain primarily to manuals for aircraft, weapons systems, and aircraft engines. Therefore, the publication numbers are listed according to aircraft, aircraft engine, and weapons system designation. Of these sections, the one pertaining to Allowance Lists is of most important to the ASH. Allowance Lists are discussed later in this chapter.

The format of the aplhanumerical listing is illustrated in figure 2-1. Specific examples of model/type part numbers pertaining to support equipment were selected to illustrate some of the various codes and abbreviated statements used throughout the Index. These entries are discussed in the following paragraphs. A complete list with explanations of all codes and statements used in the Index is contained in the Introduction, located in the first part of Volume 1. This Introduction also contains other valuable information concerning the use of the Index. It is important that all users of this Index thoroughly study this section and become familiar with its contents.

NOTE: It must be emphasized that the entries in figure 2-1 were selected to illustrate the format and use of the Equipment Applicability List. Although the information concerning these entries was current at the time of this writing, all or any part of it is subject to change from time to time. Therefore, the latest edition and supplement (discussed later) of the Equipment Applicability List must be consulted in all cases.

The column headings of the Equipment Applicability List consist of two lines. (See lines (1) and (2) of figure 2-1.) Line (1) pertains to information about the specific item of equipment. This information is listed under the appropriate headings in the line corresponding to the model/type part number, as shown in lines (3), (6), (10), (13), etc. The headings in line (2) pertain to the status of publications for each model/type part number. This information is listed on a line, or lines, under the information concerning the model/type part number. For example, the information listed in lines (4) and (5) corresponds to the headings in line (2) and pertains to the publications for the AERO46A Weapons Loader listed in line (3).

The type of information listed under each column heading is discussed in the following paragraphs.

MODEL/TYPE PART NO. - The identifying number of the specific item of equipment or system is listed in this column. Some items of equipment are identified by more than one part number. In these cases, all of the identifying numbers are listed with each number in alphanumerical sequence. For example, the numbers listed in this column on lines (6), (13), and (25) are different numbers for the same hydraulic

(1)	MODEL/TYPE PART NO.	VENDOR	NOMENCLATURE	NEXT HIGHER ASSEMBLY		SUPPL	REMARKS	SUPPL PART NO. DATA
(2)			TECH DATA NO.	TYPE	TECH DATA STK NO.	AV SC		
(3)	AERO46A	98296	WEAPONS LOADER					
(4)			19-15BE-3	05	0819-008-9000	A		
(5)			19-600-65-6-1	37	0819-042-5000	A		
(6)	AHT63	82386	HYD TEST STAND					EQUAL TO 64A99E1
(7)			17-15BF-39	15	0817-057-6000	A		
(8)			17-600-23-6-1	37	0817-110-8500	A		
(9)			17-600-23-6-4	37	0817-110-9000	A		
(10)	AN6295-1	99999	REGULATOR					
(11)			03-10ABC-504	10	0803-152-5000	A		
(12)			03-30ELE-501	10	0803-360-2000	A		
(13)	A840-0031	82386	TEST STAND					EQUAL TO AHT63
(14)			17-15BF-39	15	0817-057-6000	A		
(15)	B007	36659	PLATFORM SERVICING					SUPS COMPL 918104-1
(16)			19-15-21	12	0819-001-2000	A		
(17)	K54402	88276	DOLLY					
(18)			19-15A-41	04	-- --			
(19)	378782	70210	GAS TURBINE PLUMBING					
(20)			19-105B-15	10	0819-035-4500	A		
(21)	569180	55168	FILTER ASSY					
(22)			UNDER REVIEW		-- --			
(23)	63A109J1	99999	ULTRASONIC CLEANER					
(24)			UNDER PROCUREMENT	15	-- --			
(25)	64A99E1	82386	TEST STAND					EQUAL TO A840-0031
(26)			17-15BF-39	15	0817-057-6000	A		
(27)	682570-1	99193	REFRIGERATION UNIT		378782			
(28)			19-105B-15	10	0819-035-4500	A		
(29)	918104-1	36659	PLATFORM SERVICING					SUPSD COMPL BY B007
(30)			19-15-21	12	0819-001-2000	A		

NOTE: The sequential line numbers--(1), (2), (3), etc.--in the left margin are for explanation purposes only.

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Figure 2-1.—Format of Equipment Applicability List, NavAir 00-500A.

test stand. AHT63 is the model number, A840-0031 is the manufacturer's part number, and 64A99E1 is the Navy part number.

VENDOR - The appropriate five-digit code which identifies the contractor or government agency that manufactured the item of equipment is listed in this column. Cataloging Handbooks H4-1 and H4-2 should be referred to for the interpretation of these codes. If a vendor code is not firmly established at the time the item of equipment is listed in the Index, the code 99999 is inserted. (See lines (10) and (23) in figure 2-1.) As these vendor codes are established, appropriate changes will be made in subsequent issues of the Index.

NOMENCLATURE - A brief description of the item of equipment is listed in this column. The examples (WEAPONS LOADER, HYD TEST STAND, etc.) illustrated in figure 2-1 are typical of the descriptions used throughout the Index.

NEXT HIGHER ASSEMBLY - In some cases, technical manuals are not required for a specific item of equipment because the necessary information is, or will be, included in the technical manual(s) for the next higher assembly. In these instances, the model/type part number of the next higher assembly is listed in this column. For example, the required information for the Refrigeration Unit listed in line (27) of figure 2-1 is included in the publication for the Gas Turbine Plumbing listed in line (19). As illustrated in line (27), the part number (378782) of the Gas Turbine Plumbing is listed in the NEXT HIGHER ASSEMBLY column.

SUPPL REMARKS (Supplemental Remarks) - An entry is included in this column if the number listed under the MODEL/TYPE PART NO. is supplemented with other part number information. The descriptive statements EQUAL TO in lines (6), (13), and (25), SUPS COMPL (supersedes completely) in line (15), and SUPSD COMPL BY (superseded completely by) in line (29) are examples of the entries listed in this column. Other entries sometimes listed in this column are INTERCHANGEABLE, SUPSD PART BY (superseded partially by), and SUPS PART (supersedes partially).

SUPPL PART NO. DATA (Supplemental Part Number Data) - A part number listed in this column is associated with the statement listed in the SUPPL REMARKS column. Examples of this type entry are illustrated in lines (6), (13), (15), (25), and (29). Refer to the numbers listed in this column on lines (6), (13), and (25). As explained previously, these are different numbers for the same hydraulic test stand. Although there are three different numbers, only one is listed in each space. It should be noted, however, that regardless of which number the user of the Equipment Applicability List looks up first, he will be directed systematically through all three part numbers. For example, assume that the only number an ASH has available for this hydraulic test stand is 64A99E1. When he locates this number in the Index, he is referred to part number A840-0031. By locating this number, he is referred to AHT63. When he locates AHT63 he is referred again to the original part number, 64A99E1. This type arrangement is used throughout the Equipment Applicability List when two or more numbers are listed for the same item of equipment.

TECH DATA NO. (Technical Data Number)- The applicable current technical manual and all proposed technical manuals (those which have been numbered but have not been published) are listed in this column. The technical manuals are listed by code number as illustrated by all entries in this column of figure 2-1 with the exceptions on lines (22) and (24). (The numbering system (code numbers) for technical manuals is discussed later in this chapter.) If the technical manual numbers have not been assigned, or it has not been determined if technical manuals will be procured, or coverage will not be contained in a NavAir technical manual, a qualifying statement is entered in this column. For example, the statement UNDER REVIEW, in line (22) means that the part number has been submitted to the Naval Air Technical Services Facility (NATSF) for possible action, but no decision has been made prior to the date of the current issue of the Index. The statement, UNDER PROCUREMENT, listed in line (24) indicates that publications are being procured for this item of equipment but the publication numbers have not been assigned. The Introduction in the first part of Volume 1 of the Index should be consulted for explanations of other qualifying statements used in this column.

TYPE - A code, which corresponds to the type of technical manual, is listed in this column. For example, the number 05 in line (4) is the code for Operation and Service Instructions Manuals, and the number 37 in line (5) is the code for Maintenance Requirements Cards for Ground Support. Since the use of these particular codes is limited to the Equipment Applicability List, a complete list of the different types of manuals and their corresponding codes is listed in the Introduction in Volume 1. The different types of technical manuals applicable to the maintenance of support equipment are discussed later in this chapter. Maintenance Requirements Cards are described in chapter 4.

TECH DATA STK NO. (Technical Data Stock Number) - The Federal Stock Number for ordering the publication is listed in this column.

AV (Availability Code) - The letter "A" in this column indicates the technical manual is available and may be requisitioned from the supply system by using the applicable stock number. Before ordering, the Numerical Index, NavSup 2002, Section VIII, Part C, and its latest supplement should be checked for the complete publication title, date, and requisition restriction code. A blank space in this column indicates the technical manual is not available as of the date of the current Index and no attempt

should be made to order this manual from the supply system.

SC (Security Classification) - Technical manuals listed are unclassified unless the letter C (Confidential) or the letter S (Secret) is listed in this space.

AIRCRAFT APPLICATION LIST

The Aircraft Application List, NavAir 00-500B, contains a listing of Naval Air Systems Command technical manuals grouped according to their application to an aircraft. The aircraft are arranged by model number and are grouped in series according to their mission (Attack Series, Cargo/Transport Series, Fighter Series. etc.). The applicable technical manuals are listed by code number under each model of aircraft. The manuals are grouped in numerical sequence according to the General Classification numbers listed in table 2-1. The groups include the 00, 01, 02, 03, 05, 11, 13, 08 & 16, 17 & 18, and 19 series. Groups 00 (Allowance Lists), 17 & 18 (Machinery, Tool, and Test Equipment), and 19 (Ground Servicing and Automotive Equipment) are of most interest to the ASH.

The Aircraft Application List is especially useful for determining what manuals are available for a particular model aircraft. A listing of basic numbering categories is provided in the first few pages of the list. This listing may be used in determining the general type of equipment covered in the publication. For determining the specific item of equipment covered by a publication and the title of the publication, reference should be made to Part C of Section VIII in NavSup 2002.

DIRECTIVES APPLICATION LIST BY AIRCRAFT CONFIGURATION

Basically, the Directives Application List by Aircraft Configuration, NavAir 00-500C, is a listing of the active Naval Air Systems Command letter type technical directives (Bulletins and Changes) with respect to their applicability to an aircraft. It serves the same purpose for letter type technical directives as the Aircraft Application List does for technical manuals. The applicable technical directives are listed, by number, under each configuration of aircraft model. (NOTE: Configuration refers to modifications made to a basic aircraft model. For instance, A-4A, A-4B, TA-4F, etc., are all different configurations of the A-4 aircraft model.)

The directives are grouped according to type under each configuration of aircraft model. The types of directives consist of Airframe Bulletins and Changes, Accessory Bulletins and Changes, etc. Among these types are Support Equipment Bulletins and Changes. As indicated, these support equipment directives are applicable to specific aircraft configuration(s). Such directives may involve the modification of the aircraft to accommodate certain test or other type support equipment, the modification of an item of support equipment for a particular configuration of aircraft model, or the modification of an item of special support equipment for a particular aircraft configuration.

A "General" Series is included in the last part of NavAir 00-500C. This section consists of those technical directives which are not limited to any specific aircraft but may be pertinent to equipment used in conjunction with all or, at least, several aircraft models. 'Like the preceding sections of this Index, the listings of directives in the General section are grouped according to type. Included are listings of Support Equipment Bulletins and Changes. As indicated previously, these directives are of a general nature and often involve improvement in performance, reliability, and/or safety of the specific item of equipment. For example, Support Equipment Change 1487 is listed in this section. This directive pertains to the NHS Hydraulic Power Supply Cart and involves modifications to improve reliability and decrease service maintenance on this item of equipment.

NOTE: Bulletins and Changes are discussed in more detail later in this chapter.

EQUIPMENT AND SUBJECT APPLICABILITY LIST

The Equipment and Subject Applicability List, NavAir 00-500D, is a relatively recent addition to the Naval Aeronautic Publications Index. It contains a cross-reference index listing of Naval Air Systems Command letter type technical directives (Bulletins and Changes). It serves the same purpose for letter type technical directives as the Equipment Applicability List, NavAir 00-500A, does for technical manuals. However, since the NavAir 00-500D lists only those model/type part numbers for which technical directives have been issued, it is much smaller than the NavAir 00-500A. The complete List is contained in one volume but is divided into two

parts. Part A is the Equipment Index and Part B is the Subject Index.

Part A contains a listing of all Naval Air Systems Command letter type technical directives on aircraft components and related equipment by model/type part number. Each number is listed in alphanumerical sequence within its cognizant equipment series. At the present time, Part A is divided into nine series—Accessories, Aircrew Systems, Armament, etc. The last of these series, which is tilted Support Equipment, is of most interest to the ASH. It should be mentioned that several other types of directives are listed in this series. These pertain primarily to different types and models of Gas Turbine Compressors. The first page of the series contains a complete list of these different types of directives with a corresponding identification title code. The purpose of this code number is explained later.

NOTE: There is no title code number listed for Support Equipment Bulletins and Changes.

The information is arranged in five columns. The column headings are Model/Type Part Number, Nomenclature, Bulletin, Title Code, and Change. As previously stated, the model/type part numbers are listed in alphanumerical order within the series. A brief description of the item of equipment is listed under the column titled "Nomenclature." The numbers of the applicable Bulletins and/or Changes are listed in the columns tilted "Bulletin" and "Change," as appropriate. If the space in the column labeled "Title Code" is blank the directive is a Support Equipment Bulletin or Change. If the directive pertains to one of the other types of equipment incorporated in this series, the appropriate identification title code, mentioned previously, is listed in this space. Due to the lengthy titles of these directives, these title code numbers are used to conserve column space. It should be emphasized that these title code numbers are used for information purposes only and must not be included as part of the directive number.

Part B of NavAir 00-500D contains a listing of active Naval Air Systems Command letter type directives by subject. Since this part of the List pertains primarily to Airframe Bulletins and Changes, it is not discussed in this manual.

UPDATING THE INDEX

As indicated by the previous discussions, the different Lists of the Naval Aeronautic Publications Index provide various cross-reference lists whereby technicians and mechanics can locate and identify available technical publications applicable to specific items of equipment. The Index has undergone many changes to improve this system of indexing technical publications. As stated previously, the Equipment and Subject Application List, NavAir 00-500D, is a recent addition to the Index. Although the Equipment Applicability List, NavAir 00-500A, has been a vital part of the Index for several years, it has recently undergone a major revision which is reflected in the previous discussion. The listing of each change to manual type publications separately under different stock numbers is a recent change to Part C of the Numerical Index. Explanations of such changes are included in the introductory pages of the affected List. Therefore, when new issues of the lists are received, the introductory pages should be checked thoroughly for any changes that may have been incorporated.

The publications listed in the Index continually change. New equipment requires new publications. Old and obsolete equipment is retired and the applicable publications are canceled. Changes to equipment require additional publications and/or changes and revisions to existing publications. Therefore, some means must be provided to update the Naval Aeronautic Publications Index. To accomplish this, each List of the Index is updated at regular intervals by the issuance of a new List. In addition, some of the Lists are kept current by the periodic issuance of supplements between issues of the complete List. The methods used to update each List are discussed in the following paragraphs.

NOTE: The following information concerning the dates and intervals for the issuance of new Lists and supplements was current at the time of this writing. However, these dates and intervals have changed from time to time in the past. Therefore, the introductory pages of each new basic List and supplement should be checked for any changes of these dates and intervals.

The Numerical Sequence List (Parts C and D of NavSup Publication 2002) is issued annually. The effective date of each new issue is 1 September. A separate supplement for each Part is issued bi-monthly—November, January, March, May, and July. These supplements are cumulative; that is, all material from the preceding supplement is incorporated into the latest supplement. For example, the July supplement lists all publications that were issued, revised,

or canceled since the issuance of the May supplement plus all of the publications that were listed in the four preceding supplements. Therefore, not more than one supplement is in effect for each Part (C and D) at any given time. Naturally, the reissue of the basic List cancels the outstanding supplement.

The publications are listed in the supplement in a manner similar to that of the corresponding Part (C and D) of the basic List. That is, the items in the supplement for Part C are listed in publication number sequence in accordance with the general subject groups shown in table 2-1. New, revised, and canceled publications are all listed together in numerical sequence.

The supplement for Part D is divided into two sections. The first section lists new and revised publications in a manner similar to that of the basic List. The second section lists all canceled publications in the same format as the first section.

The Equipment Applicability List, NavAir 00-500A, is issued annually, effective 1 November. Supplements are issued quarterly—February, May, and August. The format of the supplement is the same as that of the basic List with the addition of a column which indicates whether the listed Model/Type/Part Number is new (N), changed (C), or deleted (D). Like the supplements for the Numerical Sequence List, these supplements are also cumulative.

The remaining parts of the Naval Aeronautic Publications Index are issued semiannually. The Aircraft Application List, NavAir 00-500B is issued in March and September; the Directives Application List by Aircraft Configuration, NavAir 00-500C, is issued in January and July; and the Equipment and Subject Applicability List, NavAir 00-500D is issued in May and November of each year. Supplements are not issued for these Lists.

PUBLICATIONS NUMBERING SYSTEM

Code numbers are assigned to all publications in order that they may be identified, indexed, and filed. A knowledge of the numbering systems used will enable the ASH to locate any desired information with a minimum of effort. A brief explanation of the coding of publications listed in the Index is presented in the following paragraphs.

Manuals

Code numbers assigned to manuals consist of a prefix and a series of three parts. All manual type publications are listed in the Index with the prefix NA. This is the shortened form for NavAir and identifies those publications originated by the Naval Air Systems Command. However, the prefix NW appears on some of the older publications. This is the shortened form for NavWeps and indicates those publications originated by the Bureau of Naval Weapons before it became the Naval Air Systems Command. When these publications are revised the prefix will be changed to NA.

The three parts which make up the remaining portions of the number indicate the following:

Part I is a two-digit number that indicates the general subject classification of the equipment covered by the publication. Table 2-1 lists the general subject categories and the appropriate two-digit numbers.

Part II of the publication code number consists of numbers and/or numbers and letters and indicates the specific class, group, type, or model and manufacturer of the equipment. The subject breakdowns of the 17 and 19 series are listed in table 2-2.

Part III consists of a number or numbers which designate a specific manual. For some manuals, this number designates a specific type of manual; however, for those pertaining to support equipment, this part is assigned in numerical sequence and has no reference to the type of manual.

Figure 2-2 illustrates the identification and decoding of a complete manual publication number.

Letter Type Material

There are two numbering systems used to identify letter type publications pertaining to support equipment. They are as follows:

1. Numbered in consecutive order according to specific application. For example, Support Equipment Change 590 is the 590th change that has been issued pertaining to support equipment. The changes pertaining to all support equipment are grouped together and numbered in sequence. Bulletins are numbered in the same way; however, those pertaining to specific items of auxiliary power servicing equipment are numbered separately by each item of equipment.

Table 2-2.—Subject breakdown of Series 17 and 19 manual type publications.

17 Series	**Machinery, Tools, and Test Equipment**
17-1	Shop and Warehouse Machinery, Tools and Equipment General.
17-5.	Shop and Warehouse Machinery, Powered Tools and Equipment.
17-10.	Shop and Warehouse Machinery, Powered Tools and Equipment.
17-15.	Laboratory and Shop Test and Inspection Equipment.
17-20.	Instrument Calibration Procedures.
17-25.	Measurement System Operation Procedures.
17-30.	Cross-Check Procedures.
17-35.	Miscellaneous Calibration Procedures.
17-600	Ground Support Maintenance Requirements Cards.
19 Series	**Ground Servicing and Automotive Equipment**
19-1	General.
19-5	Oxygen Equipment.
19-10.	Airfield Lighting Equipment.
19-15.	Platforms and Scaffolds.
19-20.	Portable Shop Equipment.
19-25.	Fire Trucks, Miscellaneous Trucks and Trailers.
19-30.	Field Starters (Mobile).
19-35.	Air Compressors (other than for Power Plants).
19-40.	Tractors and Aircraft Towing.
19-45.	Mobile Electric Power Plants.
19-50.	Generators for Other Than Power Plants.
19-60.	Portable Heaters and Coolers.
19-65.	Pressure Controls.
19-70.	Aircraft Hydraulic Jacks.
19-75.	Generator Skid or Trailer Mounted (Gas Nitrogen).
19-80.	Motorized Material Handling Equipment.
19-105	Gas Turbine Compressors and Power Units and Enclosures.
19-110A ...	Blower, Gasoline Driven.
19-600	Ground Support Maintenance Requirements Cards.

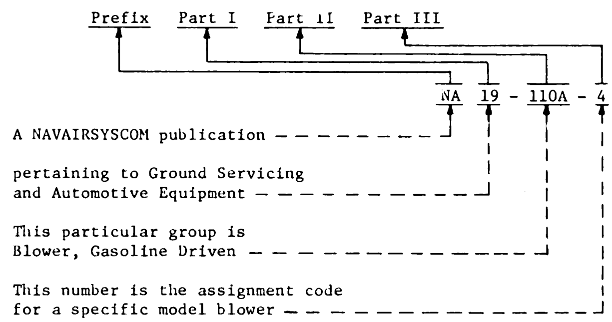

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Figure 2-2.—Identification and decoding of manual publication code number.

2. Numbered in consecutive order according to subject matter. This method covers all Naval Air Systems Command Instructions and Notices. An example is NavAir Instruction 10340.1. The number 10340 indicates the general subject of the instruction, and the .1 indicates it is the first instruction issued by the Naval Air Systems Command on that particular subject. Notices carry the general subject number only, and do not carry a point number (i.e., .1).

NOTE: Instructions and Notices are not listed in the Naval Aeronautic Publications Index.

SECURITY OF CLASSIFIED PUBLICATIONS

The Department of the Navy Security Manual for Classified Information, OpNav Instruction 5510.1 (Series), issued by the Chief of Naval Operations, is the basic security directive relating to safeguarding classified information. Its provisions apply to all military and civilian personnel and all activities of the Naval Establishment.

The manual contains detailed instructions for classifying, marking, and handling classified information, and for access to an authorized disclosure of the information.

The ASH, from time to time, has occasion to use classified publications relating to the performance of his work. Before he accepts such publications he must be cleared to the appropriate degree to handle this classified matter. It is then mandatory that he have a knowledge of and abide by the instructions in the Security Manual pertaining to handling classified material.

Publications listed in the Numerical Index (Parts C and D of Section VIII of NavSup Publication 2002) are unclassified unless otherwise marked "1" (confidential) or "4" (secret) in the column "PS" (physical security). As explained previously, classified publications listed in the Equipment Applicability List, NavAir 00-500A, are identified by the letter C (confidential) or the letter S (secret) in the column headed "SC" (security classification). Classified publications are identified in the same manner in the supplement to the respective Lists.

PROCUREMENT OF PUBLICATIONS

There are four main methods of procuring publications relating to the operation and maintenance of aviation support equipment.

The first method is initial outfitting. The Naval Air Technical Service Facility (NATSF) automatically provides the prospective commanding officer of a newly commissioned or reactivated ship, station, or activity an outfitting of general aeronautic publications.

Specific publications obtained under Aeronautic Technical Publications Outfitting Allowance constitutes another prime source of publications. Initial distribution is provided by NATSF to a newly commissioned or reactivated activity. When supported activities change mission of aircraft, support equipment requirements often change. Such changes may require a different set of publications. Upon such a change, an Aeronautic Technical Publications Outfitting Allowance, applicable to the model designation of the aircraft and equipment involved, may be obtained upon the commanding officer's letter request to NATSF.

The third source of publications is through inclusion,an automatic distribution lists. The NATSF normally provides for the issue of certain future issues of new and revised publications directly to affected activities. Activities desiring to receive future issues of new and revised publications must submit a "Mailing List Request for Aeronautic Publications" (currently Form NavAir 5605/3) to the Commanding Officer, NATSF. Personnel of the support equipment work center desiring to receive particular issues, reissues, and revisions of publications should make their requirements known to the technical library so that they may be included on the next submission of Form 5605/3.

The fourth method of procuring publications is by ordering individual publications direct. Manual type publications listed in Part C of the Numerical Index must be ordered on a Single Line Item Requisitioning System Document (DD Form 1348 or DD Form 1348m). Technical letter type publications listed in Part D of the Numerical Index must be ordered on DD Form 1149. The use of any of these three forms will not result in being placed on the distribution list to receive future issues or revisions of publications ordered.

Detailed information concerning the procurement of areonautic publications may be found in the Naval Aeronautic Publications Index.

MANUAL TYPE PUBLICATIONS

As shown in table 2-1, manuals are published in a number of different subject categories. Those of special interest to the ASH are the General Manuals (00 series) and Support Equipment Manuals (17 and 19 series). Certain manuals in other series may be used occasionally, but those listed here are of special importance to the Aviation Support Equipment Technician.

GENERAL MANUALS (00 SERIES)

As indicated by the title, this series of manuals includes information of interest to all naval aviation personnel. Included are four parts of the Naval Aeronautic Publications Index (00-500A, 00-500B, 00-500C, and 00-500D, described previously), NavAir Outfitting Lists and Allowance Lists, and Aviation Training Literature.

Outfitting Lists and Allowance Lists (00-35Q Series)

Aircraft maintenance support and repair parts for aircraft maintenance repair are listed in NavAir Initial Outfitting Lists and Allowance Lists. The equipment and parts listed in these publications are made available to aircraft operating and maintenance activities in accordance with assigned operational and maintenance responsibilities through appropriate applications of Allowance Lists and Outfitting Lists.

The Aeronautical Allowance List Program is designed to cover the various types of aircraft support equipment and repair parts considered to be required by maintenance activities.

Repair parts, nuts, bolts, etc., are included in the publications identified as Initial Outfitting Lists. Maintenance support equipment items such as test stands, aircraft jacks, lubricating guns, wrenches, drills, compass testers, and voltmeters are included in publications identified as Allowance Lists.

These Lists are identified by Sections. Certain sections such as A, H, and K are issued as individual publications. Others such as B, R, and Z appear as a series of publications, each of which is applicable to a specific model of equipment, model of aircraft, or type of activity.

The ASH should be especially familiar with the following sections:

Section G Allowance List, General Support Equipment. This section lists general handtools, consumable support equipment, and installed shop equipment.

Section K, Allowance List for Naval Aeronautic Publications and Forms.

Section M Allowance Lists. These Lists include motor vehicles, maintenance parts, and tools.

Section Z Initial Outfitting Lists. These list peculiar repair parts for mobile electric powerplants, precision measuring equipment, and peculiar and common ground support equipment.

Allowance Lists and Outfitting Lists, in conjunction with the IMRL's (explained later in this chapter), consist of listings of the equipment and material (both expendable and accountable) necessary to place and maintain activities of the aeronautical organization in a material readiness condition. Allowances contained in these Lists are based on known or estimated requirements and on available usage data.

All Allowance List and Outfitting List code numbers include NA as a prefix (discussed previously) followed with 00-35Q plus the section identification letter and a dash number to identify a particular section or series. For example, a section Z Initial Outfitting List which contains a listing of spare parts for hydraulic test stands is numbered NA 00-35QZ-39.

A program closely related to the Allowance Lists and Outfitting Lists is the Aircraft Maintenance Material Readiness List (AMMRL). This program provides for the development of data and documentation needed to determine and establish firm support equipment requirements and inventory control of aircraft maintenance support equipment. Within the AMMRL there are material readiness lists, which are discussed in the following pargraphs.

The Application Data Material Readiness List (ADMRL) is used to specify the requirements for each item of aircraft maintenance support equipment against each level of maintenance and selected ranges of each aircraft, engine, propeller, and system for which each item is needed. The initial ADMRL is established by NavAirSysCom. Through the use of data processing machines this data is used to develop Individual Material Readiness Lists.

The Individual Material Readiness List (IMRL) specifies items and quantities of ground support equipment required for material readiness of the aircraft maintenance activity to which the list applies. The list applies to an activity by name. The Naval Air Systems Command Representative is responsible for the preparation of the IMRL for each activity in his cognizant area. It is prepared by extracting from the AMMRL those applicable portions which pertain to the specific aircraft and maintenance material assignments of the activity for which the list is developed.

The IMRL should be continually reviewed and updated by each activity to support current and anticipated changes in ground support equipment requirements. Because the IMRL is continually reviewed and updated and approved by the cognizant command, it is the firm mandatory material readiness list of the activity to which the list applies.

Training Literature (00-80 Series)

This series of publications is issued by authority of the Deputy Chief of Naval Operations (Air). Included are various Air Safety Pamphlets and General Aviation Training Publications. For example, NA 00-80T-96, Aircraft Support Equipment, General Handling and Safety Precautions, is one of the training manuals in this series.

SUPPORT EQUIPMENT MANUALS (17 AND 19 SERIES)

The 17 and 19 series of aeronautic technical manuals cover most types of support equipment. The manufacturer of each item of support equipment is required to furnish adequate instructions for operating the equipment and maintaining it throughout its service life. These manuals are prepared by the manufacturer and are issued under the authority of the Naval Air Systems Command. They are then official Navy publications.

Support Equipment Manuals contain descriptive data; detailed instructions for operation, servicing, inspection, maintenance, repair, and overhaul; and illustrated parts lists. All available Support Equipment Manuals are listed in the appropriate parts of the Naval Aeronautic Publications Index. NavAir 00-500A lists available manuals in reference to the model, type, and/or part number of the equipment. All available support equipment manuals are listed in numerical order (by publication number) in Part C, Section VIII of NavSup 2002. In addition, support equipment manuals are listed (by publication number only) in NavAir 00-500B in respect to their application to each model and configuration of aircraft.

If an item of support equipment is relatively simple, all the necessary instructions may be contained in a single manual. An example is NA 19-1-60, Operation, Service, and Overhaul Instructions with Illustrated Parts Breakdown for the Aircraft Universal Towbar Assembly. More complex equipment may require two or more manuals. For example, one manual may contain operation, service, and repair instructions, while the parts breakdown is contained in a separate manual.

Regardless of the number of manuals used to contain these instructions, the terms Operation, Service, and Repair (or Overhaul) are usually used in the title of these instructions. However, some of the newer models of equipment are provided with manuals for different levels of maintenance. In this case, the manuals are titled Maintenance Instructions, Organizational Level; Maintenance Instructions, Intermediate Level; and, if required, Maintenance Instructions, Depot Level.

Operation and Service Instructions

Although sometimes issued as separate manuals, Operation and Service Instructions for each item of support equipment are usually combined into one manual, and, as previously stated, are often combined with other instructions and the parts breakdown. Operation and Service Instructions include information necessary for Organizational level maintenance.

Operation and Service Instructions Manuals are divided into sections. The manuals vary as to content and number of sections. The following is a description of the sections of a typical manual.

The first section usually contains an introduction and description of the equipment. This includes a general description and purpose of the item of equipment and brief descriptions of the major components. This section usually contains a table of specifications. These specifications include such information as the weight and overall dimensions of the equipment; capacities of the fuel, oil, and cooling systems; the manufacturer, model, and type; and leading particulars of the engine, fuel system components, electrical systems components, transmissions, etc.

In some manuals section II contains a list of special tools required for the operation and service of the equipment.

The next section gives information pertaining to the preparation of the unit for use. Instructions necessary for unpacking and assembling the unit are covered in this section. This section also includes any adjustments and inspections that must be made and any safety precautions that must be observed before the unit is operated. Some manufacturers include in this section information concerning the preparation of the unit for storage and shipment.

The next section gives complete and detailed operating procedures for the equipment. Such information as the principles of operation, the purpose and use of the operating controls, and the purpose and use of the indicating instruments are included in this section. Normal operating pressures and temperatures are also given. Safety precautions in the form of WARNINGS and CAUTIONS are inserted in the appropriate parts of the text. These same methods of presenting safety precautions are used in all support equipment instructions manuals.

The service instructions are contained in the next section. These instructions pertain to periodic inspections, maintenance, and lubrication. Charts or tables are usually used to indicate the inspection interval of systems and components. (Periodic inspections of most support equipment are performed in accordance with Maintenance Requirements Cards which are used in conjunction with the information contained in this section. Additional information concerning these inspection procedures is contained in chapter 4 of this training manual.) The specifications for oil, fuel, lubricants, etc., are included in this section. Diagrams, showing the places to be lubricated, are also included. In some manuals, troubleshooting charts are

included in this section. Other manuals contain an additional section for these charts.

The Operation and Service Instructions, as well as the other parts of support equipment manuals, usually contain illustrations to clarify the text. The illustrations provided in support equipment manuals are similar to those presented in this training manual; that is, a wide variety of graphic presentations are utilized. These include pictorial drawings (isometric drawings and reproductions of photographs), orthographic drawings, and schematic and block diagrams. Combinations of these drawings and diagrams are utilized in some illustrations.

NOTE: For detailed information concerning different types of drawings and diagrams, including the definitions of terms used in conjunction with these graphic presentations, refer to Blueprint Reading and Sketching, NavPers 10077 (Series). This manual also illustrates many of the different symbols used on diagrams.

Many of the illustrations used in support equipment manuals are pictorial drawings. Some show the complete item of equipment. The hydraulic test stand illustrated in figure 14-13 is an example of this type. In order to show more detail, some drawings feature a small portion of an item of equipment, such as the control panel illustrated in figure 14-14. In other drawings only a single component is shown; for example, the hydraulic pressure gage illustrated in figure 13-22.

Cutaway views of components are sometimes presented by pictorial drawings. The Stratopower hydraulic pump illustrated in figure 13-4 is an example of this type drawing. Exploded views, such as the mechanical drive of the Stratopower pump illustrated in figure 13-5, are used in some maintenance manuals. This type drawing is especially useful in disassembly and assembly of components. Exploded views are used extensively in Illustrated Parts Breakdown manuals, which are discussed later. Pictorial drawings are also used to show installations. These drawings are sometimes referred to as installation diagrams. Two different examples of installation diagrams are shown in parts (A) and (B) of figure 14-11.

Some of the illustrations used in support equipment manuals are presented by orthographic drawings. In this type drawing each view shows one surface of the object. The weapons loader illustrated in figure 14-12 is an example of an orthographic drawing. The top and the side views of the weapons loader are shown. Many of the cutaway views used in support equipment manuals are sectional views in the form of orthographic drawings. The sectional view featuring the fluid flow in a Stratopower pump, illustrated in figure 13-7, is an example of this type drawing. The micronic filter illustrated in figure 13-11 is an example in which a combination of pictorial and orthographic drawings is used. The first view is a pictorial drawing of the filter while the other views are sectional views (orthographic drawings) showing the flow of fluid under different conditions.

Schematic and block diagrams are commonly used to illustrate systems. These diagrams do not necessarily indicate the physical location of the components but show the relation of each component to the other components within the system. In a schematic diagram, the components are usually indicated by symbols, while in a block diagram, they are shown as blocks. In either case, the components are usually labeled by some means. The test stand hydraulic system illustrated in figure 14-16 is an example of a schematic diagram while the jack hydraulic system illustrated in figure 14-3 is an example of a block diagram. Schematic diagrams of hydraulic and pneumatic systems are very useful for tracing the flow of fluid through the systems. Therefore, these diagrams are very important aids for the ASH to learn and understand the operation of different systems and to troubleshoot malfunctions in these systems.

Repair or Overhaul Instructions

Information pertaining to Intermediate level maintenance of support equipment is usually issued as Repair or Overhaul Instructions. In some manuals this information is titled Maintenance Instructions and covers the repair and/or overhaul of the equipment.

The title of this type manual, or section of the manual, depends upon the type maintenance that must be performed on the equipment. Some equipment simply requires repair and replacement of defective parts. Repair, as it applies to maintenance of aeronautical equipment, is the restoration of an item of equipment to an acceptable operating condition without complete disassembly and inspection. The maintenance information required for this type equipment is usually issued as Repair Instructions.

Some items of support equipment must be overhauled at regular intervals. Overhaul is

the disassembly of an item of equipment as required to permit inspection of every component part. Component parts which, upon inspection, will not meet requirements as set forth in applicable specifications are restored or replaced by new parts so that after reassembly and test, the equipment will meet the requirements set forth in the applicable specifications. Maintenance information of this type is generally issued as Overhaul Instructions. The overhaul intervals (number of miles, number of starts, hours of operation, months of operation, etc.) are specified in the Overhaul Instructions.

If the Repair or Overhaul Instructions are published as a separate manual, the first section is a brief introduction. This includes the purpose and leading particulars of the item of equipment. The remainder of the manual contains complete repair or overhaul instructions and test procedures. If combined with the Operation and Service Instructions, the Repair or Overhaul Instructions are arranged in a section, or sections, following the service instructions.

Illustrated Parts Breakdown

The purpose of the Illustrated Parts Breakdown (IPB) is to assist supply and maintenance personnel in the identification, requisitioning, and issuing of parts for the applicable item of support equipment.

The IPB for some complex items of support equipment is issued as a separate manual and, of course, has its own identification number. The IPB for most items of support equipment is combined with one or more sections of the instructions manuals and is the last section or sections of the manual. An example of the title of a combined manual is Operation and Service Instructions with Illustrated Parts Breakdown.

Although the IPB appears in some manuals as one section, it is usually divided into three sections or parts—Introduction, Group Assembly Parts List, and Numerical Index. In addition to these three parts, a Table of Contents is provided. If the IPB is a separate manual, the Table of Contents is contained in the first few pages of the manual. If the IPB is combined with instructions manuals, a combined Table of Contents appears in the first few pages of the combined manual. In either case, the Table of Contents contains a List of Illustrations which plays an important role in locating parts in the IPB. This is discussed later.

The Introduction contains detailed instructions for the use of the IPB. All the information in this section should be read prior to using the remaining sections. The information in the Introduction will aid the ASH in locating the necessary part or parts quickly and easily.

The next section, Group Assembly Parts List, lists and illustrates the assemblies and parts of the equipment. As mentioned previously, exploded views are usually used to illustrate these assemblies and parts. The parts lists are used in conjunction with the illustrations. Index numbers in the parts lists correspond to those on the illustrations. This section and the List of Illustrations, mentioned previously, are used to locate and identify a part when the part number is unknown. The steps involved in this process are presented in figure 2-3.

The last section, the Numerical Index, contains an alphanumerical listing of all the parts in the IPB. In addition to the part numbers, the Numerical Index contains such information as federal stock number data, figure and index numbers, source code data, and repair code.

The numerical Index is used to find the illustration and nomenclature of a part if the part number is known. Figure 2-4 illustrates the steps involved in this process.

DESCRIPTIVE DATA SHEETS FOR AVIATION SUPPORT EQUIPMENT (20 SERIES)

The sheets provide a consolidated source of descriptive information about individual items of aviation support equipment not available elsewhere.

The type of data furnished on these sheets includes the following:

Official nomenclature of the item.

Manufacturer and model/type number.

Functional classification.

Federal stock number.

A photograph or drawing of the item.

Functional description (purpose).

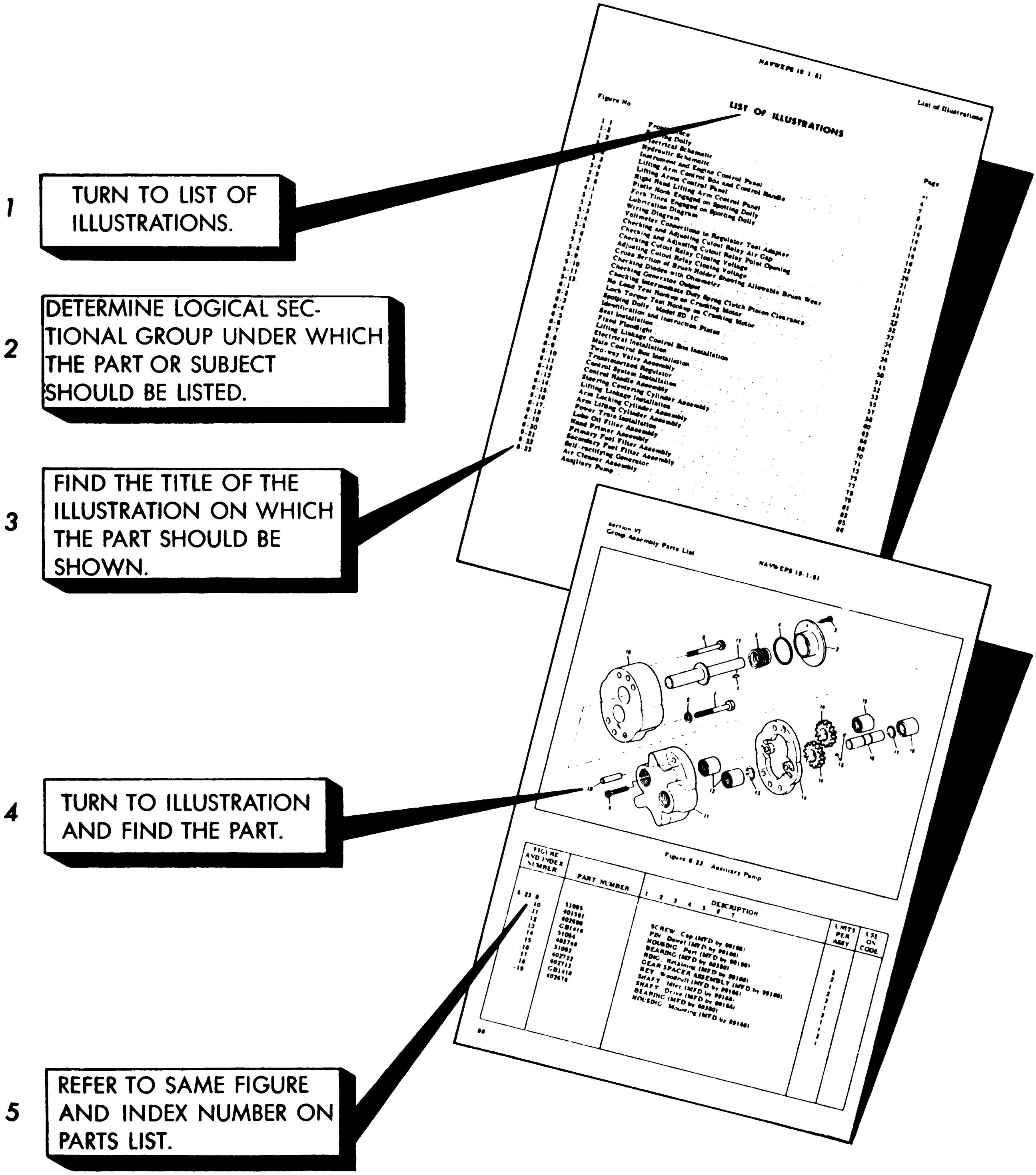
Its relation to other equipment.

Electromechanical/mechanical description (technical details).

Reference data and literature available about the item.

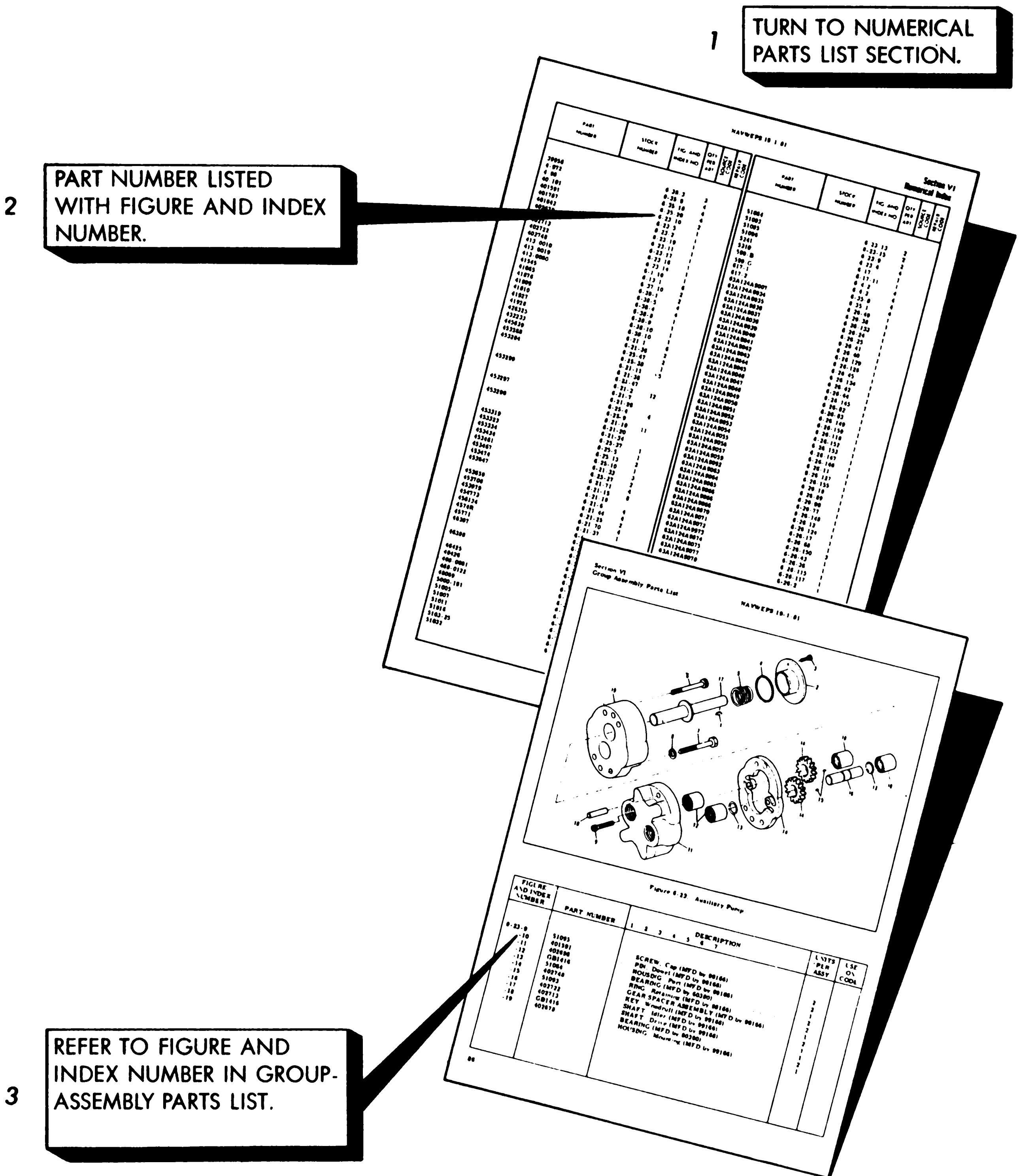
Shipping data (size, weight, etc.).

NOTE: At the time of this writing, the 20 Series Descriptive Data Sheets are being superseded by MIL-HDBK-300B, Military Standardization Handbook, Technical Information File of



AS.670

Figure 2-3.—How to use the Illustrated Parts Breakdown when the part number is unknown.



AS.671

Figure 2-4.—How to use the Illustrated Parts Breakdown when the part number is known.

Ground Support Equipment. This handbook, which contains several volumes, provides descriptive information similar to that listed for Descriptive Data Sheets. However, it includes ground support equipment used by the Air Force, Army, and Navy.

UPDATING OF MANUALS

Modern technology is a constantly changing thing. What is considered to be the "latest" word today may be modified, totally revised, or otherwise made obsolete tomorrow. This is not always a planned or intended condition, but it must be accepted and dealt with.

These changing conditions apply to aeronautic technical publications. They require that prompt action be afforded to change and revise all material which is related to the technical information and data used by maintenance and operational personnel.

The degree of urgency of updating publications depends upon the type of information involved and the frequency of reference to the affected publications. In any event, technical data change and revision material should not be allowed to accumulate at any point.

Copies of these changes and revisions, received through the proper submission of NavAir Form 5605/3, are first delivered to the technical library. Personnel of the library, of course, make the necessary changes to the affected publications filed in the library. However, the changes affecting the publications held by the production divisions are routed to the appropriate work center. Personnel of the work center are then required to incorporate the changes into their copies of the affected publications.

The changes or revisions are prepared by the manufacturer of the specific equipment and are issued under the authority of the Naval Air Systems Command. The changes or revisions may direct write-in changes, provide replacement/additional pages, and/or provide information affecting various parts of the manual, in which case the information is prepared as supplemental data.

When incorporating changes, the instructions provided on the front page of the change should be followed exactly. Write-in material should be entered neatly and legibly using indelible ink. Text material to be deleted should have a single line ruled neatly through every line of type.

Supplemental data is supplied on pages to be filed next to the affected pages in the manual. Supplementary pages are inserted in the manual in page number order and are identified by a letter added to the page number. For example, if a supplementary page is issued bearing the number 2-16A, it is placed between pages 2-16 and 2-17. The supplementary information may be applicable to either or both of these pages.

Replacement pages are designed to replace pages already in the basic publication. They are numbered in exactly the same way as the pages they replace. The date of the change is shown on the bottom of the page in the corner opposite the page number. Prior to incorporating replacement pages they should be counted and the number noted. When the task is finished, the removed pages should be counted to make sure that the same number were removed as were put in. Also, the bottom of each removed pages should be checked for dates to make sure no new replacement pages were inadvertently missed.

On the back of each change notice cover page is a cumulative list of all changed/revised pages issued and the date of issue, since the basic date of the manual. Checking the listed pages and dates against the corresponding pages of the manual, which are also dated, provides one method of determining currentness and completeness of the manual. This page becomes the cover page of the revised manual.

In addition to the normal technical manual change and revision system described above, a Rapid Action Change (RAC) system has been developed recently to improve the timely issuance of urgently required information. Under this system, information affecting flight safety, hazards to personnel, or grounding of aircraft is disseminated via naval message and immediately incorporated in the affect manual. A manual charge page follow-up is then required within 15 days of the release of the message. As indicated by the type of information disseminated in this manner, this system pertains primarily to aircraft technical manuals. However, support equipment can indirectly affect flight safety and grounding of aircraft and can directly cause hazards to personnel. Therefore, the RAC system is applicable to support equipment manuals. In addition to the message type of change, information of a less urgent nature is disseminated by RAC change pages

that must be printed within 30 days after problem resolution and is generally limited to 12 pages or less.

It should be emphasized that the RAC system does not affect the normal change and revision requirements. The RAC system merely supplements the existing change system to provide for rapid issue of urgently required data.

LETTER TYPE PUBLICATIONS

There are two broad categories of letter type publications. One category pertains to information of a technical nature and includes Bulletins and Changes. This category is referred to as Technical Directives. The other category pertains to policy and administration procedures. Instructions and Notices are used to disseminate this type of information. These different forms of letter type publications are discussed in the following paragraphs.

TECHNICAL DIRECTIVES

The Technical Directive System has been established for the control and issue of all technical directives. This system standardizes the method of issuance for such directives and is the authorized means for directing the accomplishment and recording of modifications and one-time inspections of ground support equipment as well as aircraft and other aeronautical equipment. The Technical Directive System is an important element in the programs designed to maintain equipment in a safe and current state of operational and material readiness.

This system provides for two types of technical directives. The types are determined by the method of dissemination. The two types are Formal (letter type) and Interim (message type). In general terms, they are both considered as letter type publications. Such directives contain instructions or information of a technical nature which cannot be disseminated by revisions or changes to technical manuals. However, the accomplishment of a technical directive often necessitates a change or revision to the applicable technical manual. Technical directives are issued in the form of Changes, or in the case of special circumstances, by Interim Changes or Interim Bulletins.

A formal technical directive is issued as a Change, or as an amendment or revision thereto, and, as stated previously, is disseminated by letter. Formal directives are used to direct the accomplishment and recording of modifications to support equipment, as well as aircraft and related equipment. An interim technical directive is issued as a Change or a Bulletin, or as an amendment or revision thereto, and, in order to insure prompt delivery to the concerned activities, is disseminated by message. The interim technical directive is reserved for those instances to correct a safety or operational condition whenever it is considered too important to risk waiting for the issuance of a formal directive.

Each interim Change is superseded by a Formal Change directive which will have the same number as the interim directive. Interim Bulletins are not superseded by formal Bulletins as was previously the case. NavSup Publication 2002, Section VIII, Part D will still have many formal Bulletins listed until they are eventually phased out.

A Change is a document containing instructions and information which directs the accomplishment and recording of a material change, a repositioning, a modification, or an alteration in the characteristics of the equipment to which it applies. A Change is issued to direct that parts be added, removed, or changed from the existing configuration or that parts or material be altered, relocated, or repositioned.

A Change may be issued in parts to accomplish distinct parts of a total directed action or to accomplish action on different configurations of affected equipment.

A Bulletin is an interim document comprised of instructions and information which directs an initial inspection to determine whether a given condition exists. It specifies what action is to be taken if a given condition is found or not found.

Sometimes it is found that a Change or Bulletin is not the complete answer to a problem, and it is determined necessary to amend or revise an outstanding directive. An Amendment is a document comprised of informtaion which clarifies, corrects, adds to, deletes from, makes minor changes in requirements to, or cancels an existing directive. It is only a supplement to the existing directive and not a complete directive in itself. A maximum of three Amendments may be applied to any technical directive, each remaining in effect until rescinded or superseded by a Revision. A requirement for further amendment action necessitates the issuance of a Revision.

A Revision is a completely new edition of an existing technical directive. It supersedes the original directive and all existing Amendments.

Interim Bulletins are self-rescinding with rescission dates of 30 June and 31 December, whichever is appropriate for the case at hand. Rescission is the process by which a technical directive is removed from active files after all requirements have been incorporated and recorded. Rescinding dates are also projected for formal changes. Final rescission action of all technical directives is directed in Part D, Section VIII, NavSup Publication 2002. All activities maintaining files of technical directives should retain all technical directives until they are deleted from NavSup Publication 2002.

Changes and Bulletins are issued by technical personnel of the Naval Air Systems Command and are based on Contractor Service Bulletins, on reports from various Data Services, or letters of recommendation or proposed modifications from field service activities. They are automatically distributed to all activities concerned through inclusion on the Mailing List Request for Aeronautic Publications, NavAir 5605/3.

Changes and Interim Changes are assigned numbers in a numerical sequence by the Technical Directives Control Center, located at the Naval Air Technical Services Facility (NATSF), Philadelphia, Pa. As stated previously, a Formal Change which supersedes an Interim Change will have the same number as the Interim Change. Interim Bulletins are numbered similarly in another number series.

The title of a Change or Bulletin for support equipment is made up of three parts. Part one is the term "Support Equipment " part two, the word or words "Change," "Interim Change," or "Interim Bulletin;" and part three, the sequential number. When applicable, the words "Rev. A," "Amendment 1," etc., follow the basic directive.

Changes are classified by various "action" categories. Bulletins may also be assigned an action classification, but it is not mandatory. The assigned action category serves as a priority for compliance with the various directives.

The category "Immediate Action" is assigned to directives which are issued to correct safety conditions, the incorrected existence of which would probably result in fatal or serious injury to personnel, extensive damage, or destruction of property. Immediate Action directives involve the discontinued use of the equipment in the operational employment under which the adverse safety condition exists, until the directive has been complied with. If the use of the equipment will not involve the use of the affected component or system in either normal or emergency situations, compliance may be deferred, but should be accomplished no later than 120 days from the date of issue. Immediate Action directives are identified by a border of red X's, broken at the top center of the page by the words "IMMEDIATE ACTION," also printed in red.

The category "Urgent Action" is assigned to directives which are used to correct safety conditions which, if uncorrected, could result in personnel injury or property damage. This category of directive is identified by the words "URGENT ACTION" printed in red ink at the top of the first page and a border of red diagonals around the cover page.

The compliance requirements for Urgent Action directives specify that the incorporation of the instructions must be accomplished not later than the next regularly scheduled rework or overhaul or, for equipment not reworked or overhauled, on a regularly scheduled basis, not later than 18 months after the date of issuance.

Routine Action directives are issued where there are reliability, capability, or maintainability deficiencies which could, if uncorrected, become a hazard through prolonged usage or have an adverse effect on the operational life or general service utilization of equipment. The compliance requirement specifies the incorporation of the instructions not later than the next regularly scheduled overhaul or rework, or for equipment not reworked or overhauled on a scheduled basis, not later than 18 months after issuance of the directive. If accomplishment of the work requires Depot level maintenance capability, the compliance may be deferred if it will seriously interfere with operational commitments or schedules. Routine Action directives are identified by the words "ROUTINE ACTION" printed in black capital letters at the top center of the cover page.

Record Purpose category is assigned to a technical directive when a modification has been completely incorporated by the contractor before acceptance by the Navy. This category of technical directive merely documents the action for configuration management purposes. Consequently, compliance information is not applicable. They are identified by the words "RECORD PURPOSES" printed in black capital letters at the top center of the cover page.

INSTRUCTIONS AND NOTICES

Instructions and Notices are directives containing information and instructions concerning policy, administration, and air operations. They are issued by all systems commands, bureaus, ships, stations, and operating activities. Those issued by the Naval Air Systems Command are known as NavAir Instructions and Notices.

Instructions are directives of a continuing nature and are effective until canceled or superseded by a later directive.

Notices are directives of a one-time nature or directives which are applicable for a brief period of time. Each Notice contains a provision for its own cancellation.

Instructions are numbered in consecutive order according to the subject covered in the Instruction. Notices are not assigned consecutive numbers because of their one-time nature or brief duration. For this reason, the date must always be used when referring to a Notice. Those Instructions and Notices pertaining to aviation maintenance may be addressed to "All Ships, Stations, and Units concerned with Naval Aircraft," or to certain activities only. Each activity maintains a file of all pertinent Instructions and Notices still in effect.

MISCELLANEOUS AVIATION PUBLICATIONS

Several unofficial publications of general interest to aviation personnel are available in most operating activities. These should be read regularly by all maintenance personnel.

NAVAL AVIATION NEWS

The Naval Aviation News, NavAir 00-75R-3, is published monthly by the Chief of Naval Operations and the Naval Air Systems Command. Its purpose is to disseminate data on aviation training and operations, aviation support equipment, space technology, missile, rocket, and other aviation ordnance developments, aeronautical safety, aircraft design, powerplants, aircraft recognition, technical maintenance, and overhaul procedures.

As its name implies, this publication is essentially a news magazine. It enables readers to keep abreast of the latest unclassified developments in every facet of naval aviation. In addition, the coverage of fleet operations and the human interest articles on the noteworthy feats and accomplishments of individuals, both officer and enlisted, make the Naval Aviation News an entertaining as well as an informational periodical.

APPROACH

Approach (NavAir 00-75-510), The Naval Aviation Safety Review, is published monthly by the U.S. Naval Aviation Safety Center and is distributed to all naval aeronautic organizations on the basis of 1 copy for every 10 persons. It presents the most accurate information currently available on the subject of aviation accident prevention.

A large number of aviation accidents are maintenance-induced; that is, they occur during preparation for, performance of, and securing from maintenance or as a result of sloppy or improper maintenance. Some aviation accidents result, either directly or indirectly, from careless use or improper maintenance of support equipment. Therefore, articles concerning aviation support equipment frequently appear in this magazine. For example, a recent article recommended that tires with military tread be used on support vehicles to decrease FOD (foreign object damage) to aircraft. (This is discussed further in chapter 11 of this manual.) In addition, many hints on general maintenance are issued in the Approach. Although these are primarily for aircraft maintenance personnel, they may also apply to the maintenance of support equipment. For example, a recent issue discussed the care of bearings, and another the use and care of torque wrenches.

The Approach magazine reports the results of accident investigations; and for those accidents that are maintenance-induced, describes what was done wrong and how it should have been done; suggests corrective measures to prevent future accidents resulting from these causes; and when appropriate, cites aeronautic technical publications which provide authority for changes in techniques or material to improve the maintenance product.

In short, the maintenance man who reads and heeds the messages in Approach is the man who benefits from other mechanics' experiences. Put Approach on your required reading list and look for it every month.

CHAPTER 3
ELEMENTARY PHYSICS

The Aviation Support Equipment Technician H is associated with some very complex machines and equipment. He is expected to understand, operate, service, and maintain these machines and equipment, and to instruct new men so that they can also perform these functions. No matter how complex a machine or item of equipment, its action can be satisfactorily explained as an application of a few basic principles of physics. In order to understand, maintain, and repair the equipment and machinery necessary to the operation of the ships and aircraft of the fleet, an understanding of these basic principles is essential. There can be no question that the technician who possesses this understanding is better equipped to meet the demands placed upon him in his everyday tasks. Therefore, it is only fitting that a knowledge factor—elementary physics of heat, light, sound, fluids, gases, and electricity—is included in the minimum requirements for advancement to ASH3.

Physics is devoted to finding and defining problems, as well as to searching for their solutions. It not only teaches a person to be curious about the physical world, but also provides a means of satisfying that curiosity. The distinction between physics and other sciences cannot be well defined, because the principles of physics also pertain to the other sciences. Physics is a basic branch of science and deals with matter, motion, force, and energy. It deals with the phenomena which arise because matter moves, exerts force, and possesses energy. It is the foundation for the laws governing these phenomena, as expressed in the study of mechanics, hydraulics, magnetism, electricity, heat, light, sound, and nuclear physics. It is closely associated with chemistry and depends heavily upon mathematics for many of its theories and explanations.

BASIC CONCEPTS

In any study of physics, it soon becomes obvious that specific words and terms have specific meanings which must be mastered from the very start. Without an understanding of the exact meaning of the term, there can be no real understanding of the principles involved in the use of that term. Once the term is correctly understood, however, many principles may be discussed briefly to illustrate or to emphasize the particular aspects of interest. The first part of this chapter is devoted to definitions of some physical terms and a brief general discussion of certain particular principles of vital interests to all technical personnel.

MEASUREMENT

In all branches of science, measurement is a very important consideration. In order to evaluate results, it is often essential to know how much, how far, how many, how often, or in what direction. As scientific investigations become more complex, measurements must become more accurate, and new methods must be developed to measure new things.

Measurements may be classed in three broad categories—magnitude, direction, and time. These categories are broken down into several types, each with its own standard units. Measurements of direction and time have become fairly well standardized and have comparatively few subdivisions. Magnitude, on the other hand, is an extremely complex category with many classes and subdivisions involved.

To illustrate the complexity of the magnitude category, consider only a few common examples of measurement dealing with magnitude—weight, distance, temperature, voltage, size, loudness, brightness, etc.; then consider measurements based on combinations of magnitude—density (weight per unit volume), pressure (force per unit area), thermal expansion (increase in size per degree change in temperature), etc. In addition, measurements combine categories: The flow of liquids is measured in volume per unit of time, speed is measured in distance per unit of time, rotation is measured in revolutions per minute, frequency is expressed in hertz, and so on, indefinitely. (The term "hertz" (Hz)

has the same meaning and is replacing the term "cycles per second.")

The importance of measurement and the necessity of selecting the proper measurement cannot be overemphasized. Several systems of measurement further complicate matters. For example, distance may be measured in feet or in meters; weight in pounds or in kilograms; capacity in quarts or in liters; temperature in degrees Fahrenheit, Celsius, or Kelvin; density in pounds per cubic foot or in grams per cubic centimeter; angles in degrees or in radians; etc.

In this manual, as in many other texts, specific measurements will be described when and as necessary for clarity.

MATTER AND ENERGY

MATTER may be defined basically as "anything that occupies space and has weight." It exists naturally in three states—solid, liquid, or gas. All matter is composed of small particles called molecules. Matter may be changed or combined by various methods—physical, chemical, or nuclear. Matter has many properties; properties possessed by all forms of matter are called general properties, while those properties possessed only by certain classes of matter are referred to as special properties.

ENERGY may be defined basically as "the capacity for doing work." It may be classified in many ways; but for this discussion, energy will be classified as mechanical, chemical, radiant, heat, light, sound, electrical, or magnetic. Energy is constantly being exchanged from one object to another and from one form to another. Physics is primarily the study of matter and energy in their various forms and of the relationships that exist between them.

Law of Conservation

Matter may be converted from one form to another with no change in the total amount of matter. Energy may also be changed in form with no resultant change in the total quantity of energy. In addition, a third statement has been added within the past half century: "Although the total amount of matter and energy remains constant, matter can be converted into energy or energy into matter." This statement is known as the law of conservation for energy and matter. The basic mathematical equation which shows the relationship between matter and energy is as follows:

$$E = mc^2$$

where E represents the amount of energy, m represents the amount of matter (mass), and c represents the velocity of light.

From the equation it may be seen if energy appears, some matter must have disappeared. If energy disappears, matter must always appear in its place. From this observation it may be implied that a given quantity of matter is the equivalent of some amount of energy. In common usage it is usually stated that matter "possesses" energy.

General Properties of Matter

Matter in all forms possesses certain properties. In the basic definition it has been stated that matter occupies space and has weight. Those two ideas contain most, if not all, of the general properties of matter.

SPACE.—The amount of space occupied by or enclosed within, the bounding surfaces of a body is called volume. In the study of physics, this concept must be somewhat modified in order to be completely accurate. As stated previously, matter may appear as a solid, as a liquid, or as a gas—each having special properties. In a later section of this chapter it will be shown that for even a specific substance the volume may vary with changes in circumstances. It will also be shown that liquids and solids tend to retain their volume when physically moved from one container to another; gases tend to assume the volume of the container.

It will be discussed at some length later that all matter is composed of atoms and molecules. In order to clarify this concept of "occupying space," these minute particles of matter, which are in turn composed of still smaller particles separated from each other by empty space (which contains no matter), must be understood. This idea is used to explain two general properties of matter—impenetrability and porosity.

Two objects cannot occupy the same space at the same time; this is known as the "impenetrability of matter." The actual space occupied by the individual subatomic particles cannot be occupied by any other matter. The impenetrability of matter may, at first glance, seem invalid when a cup of salt is poured into a cup of water—the result is considerably less than two

cups of salt water. However, matter has an additional general property called "porosity" which explains this apparent loss of volume: The water simply occupies space between particles of salt. Porosity is present in all material—but to an extremely wide range of degree. Generally, gases are extremely porous, liquids only slightly so; solids vary over a wide range, from the sponge to the steel ball.

WEIGHT.—The concept of weight is also quite complicated and involves two general properties of matter—inertia and gravitational attraction. Before discussing weight, these two general properties and the concepts of motion and force must be discussed.

MOTION may be defined as the "act or process of changing place or position." The "state of motion" refers to the amount and the type of motion possessed by a body at some definite instant (or during some interval) of time. A body at rest is not changing in place or position; it is said to have zero motion, or to be motionless.

The natural tendency of any body at rest is to remain at rest; a moving body tends to continue moving in a straight line with no change in speed or direction. A body which obeys this natural tendency is said to be in uniform motion.

Every object tends to maintain a uniform state of motion. A body at rest never starts to move by itself; a body in motion will maintain its speed and direction unless it is caused to change. In order to cause a body to deviate from its condition of uniform motion, a push or a pull must be exerted on it. This requirement is due to that general property of all matter known as INERTIA.

The greater the tendency of a body to maintain uniform motion, the greater its inertia. To assign a numerical value to the inertia of a body, it is compared with some standard which is assigned the inertia value of 1. The quantitative measure of inertia is called the MASS of the body; therefore, since all matter possesses inertia, all matter must also possess mass.

Any change in the state of motion of a body is known as ACCELERATION, and the cause which produces it is called an accelerating-force. Acceleration represents the rate of change in the motion of a body, and may represent either an increase or a decrease in speed and/or a change in direction of motion.

FORCE is the action or effect on a body which tends to change the state of motion of the body acted upon. A force may tend to move a body at rest; it may tend to increase or decrease the speed of a moving body; or it may tend to change the direction of motion. The application of a force to a body does not necessarily result in a change in the state of motion; it may only TEND to cause such a change.

A force is any push or pull which acts on a body. Water in a can exerts a force on the sides and bottom of the can. A tug exerts a push or a pull (force) on a barge. A man leaning against a bulkhead exerts a force on the bulkhead.

In the above examples, a physical object is exerting the force and is in direct contact with the body upon which the force is being exerted. Forces of this type are called contact forces. There are other forces which act through empty space without contact—in some cases without even seeming to have any mass associated with them. The force of gravity exerted on a body by the earth—known as the weight of the body—is an example of a force that acts on a body through empty space and without contact. Such a force is known as an action-at-a-distance force. Electric and magnetic forces are other examples of these action-at-a-distance forces. The space through which these action-at-a-distance forces are effective is called a force field.

Force is a VECTOR quantity; that is, it has both direction and magnitude. A force is completely described when its magnitude, direction, and point of application are given. In a force vector diagram, the starting point of the line represents the point of application of the force. (The topic of vectors—properties, functions, uses, and methods of calculation—is discussed in detail in the Rate Training Manual, Mathematics, Vol. 2, NavPers 10071 (Series).)

Any given body, at any given time, is subjected to many forces. In many cases, all these forces may be combined into a single RESULTANT force, which may then be used to determine the total effect on the body. Combination of all individual forces into a single resultant involves the use of trigonometry, which is also covered in NavPers 10071 (Series).

Each body of matter in the universe attracts every other body with a force which is proportional to the mass of the bodies and inverse to the square of the distance between them. This force is called the UNIVERSAL FORCE OF GRAVITATIONAL ATTRACTION. Since every body exerts this force on every other body, when considering the forces acting on a single body, it is an almost universal practice to

resolve all gravitational forces into a single resultant. At or near the surface of the earth, this becomes a fairly simple process—due to its extremely large mass, the earth exerts such a large gravitational attraction that it is entirely practical to ignore all other such attractions and merely use the earth's gravitational attraction as the resultant.

Although gravitational attraction is exerted by each body on the other, in those cases where there is a great difference in the mass of two bodies, it is usually more convenient to consider the force as being exerted by the larger mass on the smaller mass. Thus, it is commonly stated that the earth exerts a gravitational force of attraction on a body. The gravitational attraction exerted by the earth on a body is called GRAVITY.

The gravitational force exerted by the earth on a body is called the WEIGHT of that body, and is expressed in force units. In the English system, force is expressed in pounds. If a body is attracted by a gravitational force of 160 pounds, the body is said to weigh 160 pounds. The gravitational force between two bodies decreases as the distance between them increases; therefore, a body weighs less when positioned a mile above the surface of the sea then it weighs at sea level—it weighs more if positioned a mile below sea level.

Conversion of Mass and Weight

The relationship of mass, weight, and gravity may be expressed mathematically by the formula

$$\text{mass} = \frac{\text{weight}}{\text{acceleration due to gravity}}$$

This relationship is valid for any system of measurement, provided only that all measurements are taken in the same system.

In the English system of measurement, the mass is normally measured in slugs, weight in pounds, and acceleration (due to gravity) in feet per second per second. Therefore, the equation in English terms is

$$m = \frac{w\ (\text{lb})}{g\ (\text{ft/sec}^2)}$$

(A slug is frequently defined in terms of force and acceleration: A slug is that mass which, when acted upon by a force of 1 pound, will be accelerated by 32 ft/sec^2.)

In problems involving the use of mass, it is usually convenient to substitue w/32 for m and the weight of the body for w in the equation. (The 32 comes from the fact that the acceleration due to gravity is 32 ft/sec^2.)

Example 1: If a body has a mass of 5 slugs, its weight (in pounds) at sea level (as measured with a spring balance) may be determined from the formula

$$m = \frac{w}{g}$$

Rearranged to solve for the necessary quantity, this formula becomes

$$w = mg$$

Substituting the numerical values,

$$w = 5 \times 32$$

$$w = 160 \text{ lb}$$

The spring-balance weight of the object is 160 lb at sea level.

Example 2: At an altitude where the acceleration due to gravity is only 31.5 ft/sec^2, what is the weight of the 5-slug mass? By using the same equation and substituting numerical values

$$w = mg$$

$$w = 5 \times 31.5$$

$$w = 157.5 \text{ lb}$$

These examples illustrate how weight varies as a result of a change in the force of gravity due to a change in altitude. The value of 32 feet per second per second, usually assigned g, is only an approximation used when measurements are made at or near sea level. Altitude affects the weight of an object, but its mass remains constant everywhere.

It is interesting to note that spring weighing machines are not legal for trade in most states of the U.S. A spring scale registers the force necessary to overcome the pull which gravitational force exerts on the object being weighed. This gravitational force varies with the altitude of the object on the earth. A balancing scale, usually called a BALANCE, measures mass rather than weight, although the dial is marked in pounds. On a balance, the object to be

weighed is compared with a standard unit of mass. The variation due to altitude is canceled because it affects both the standard unit and the object to be weighed. Therefore, the standard mass serves as an accurate unit of measure for all locations on the surface of the earth.

Density and Specific Gravity

The DENSITY of a substance is its weight per unit volume. A cubic foot of water weighs 62.4 pounds; the density of water is 62.4 pounds per cubic foot. (In the metric system the density of water is 1 gram per cubic centimeter.)

The SPECIFIC GRAVITY (sp gr) of a substance is the ratio of the density of the substance to the density of water—

$$\text{sp gr} = \frac{\text{weight of substance}}{\text{weight of equal volume of water}}$$

Specific gravity is not expressed in units but as a pure number. For example, if a substance has a specific gravity of 4, 1 cubic foot of the substance weighs 4 times as much as a cubic foot of water—62.4 times 4 or 249.6 pounds. In metric units, 1 cubic centimeter of a substance with a specific gravity of 4 weighs 1 times 4 or 4 grams. (Note that in the metric system of units, the specific gravity of a substance has the same numerical value as its density.)

Specific gravity and density are independent of the size of the sample under consideration, and depend only upon the substance of which the sample is made. See table 3-1 for typical values of specific gravity for various substances.

A great deal of ingenuity is often needed to measure the volume of irregularly shaped bodies. Sometimes it is practical to divide a body into a series of regularly shaped parts and then apply the rule that the total volume is equal to the sum of the volumes of all individual parts. Figure 3-1 demonstrates another method of measuring the volume of small irregular bodies. The volume of water displaced by a body submerged in water is equal to the volume of the body.

A somewhat similar consideration is possible for floating bodies. A floating body displaces its own weight of liquid. This may be proved by filling a container to the brim with liquid, then gently lowering the body to the surface of the liquid and catching the liquid that flows over the brim. Weighing the liquid displaced and the original body will prove the truth of the statement.

Table 3-1.—Typical values of specific gravity.

Substance	Specific gravity
Aluminim	2.7
Brass	8.6
Copper	8.9
Gold	19.3
Ice	0.92
Iron	7.8
Lead	11.3
Platinum	21.3
Silver	10.5
Steel	7.8
Mercury	13.6
Ethyl alcohol	0.81
Water	1.00

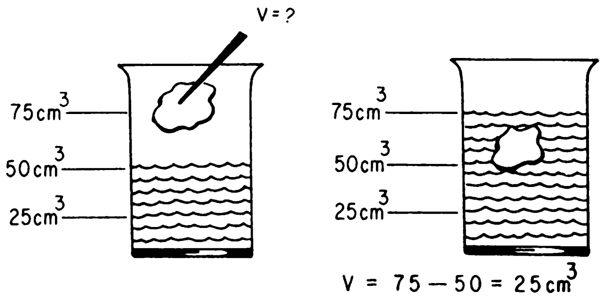


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Figure 3-1.—Measuring the volume of an irregular object.

Pressure and Total Force

Pressure and force, while closely related topics, are not the same thing. A weight of 10 pounds resting on a table exerts a force of 10 pounds. However, the shape of the weight must be taken into consideration to determine the effect of the weight. If the weight consists of a thin sheet of steel resting on a flat surface, the effect is quite different than if the same sheet of steel were resting on a sharp corner.

Pressure is concerned with the distribution of a force with respect to the area over which that force is distributed. Pressure is defined as the force per unit of area, or P = F/A. A flat pan of water with a bottom area of 24 square inches and a total weight of 72 pounds exerts a total force of 72 pounds, or a pressure of 72/24 or 3 pounds per square inch, on the flat table. If the pan is balanced on a block with a surface area of 1 square inch, the pressure is 72/1 or 72 pounds per square inch. An aluminum pan with a thin bottom is suitable for use on a flat surface, but may be damaged if placed on the small block.

This concept explains why a sharp knife cuts more easily than a dull one. The smaller area concentrates the applied force (increases the pressure) and penetrates more easily. For hydraulic applications, the relationship between pressure and force is the basic principle of operation. In enclosed liquids under pressure, the pressure is equal at every point on the surfaces of the enclosing container, and therefore the force on a given surface is dependent on the area. In a system consisting of two cylinders connected by a tube, the force on the pistons is proportional to the areas.

Kinetic Energy

Moving bodies possess energy because, by virtue of their mass in motion, they are capable of doing work. The energy of mass in motion is called KINETIC energy, and may be expressed by the equation

$$\text{Kinetic energy} = 1/2\ mv^2$$

where m represents the mass of the body, and v is the velocity of its motion. When the moving body is stopped, it loses its kinetic energy. The energy is not destroyed, but is merely converted into other forms of energy, such as heat and POTENTIAL energy. It is important to remember that bodies at rest also possess energy by virtue of their position.

COMPOSITION OF MATTER

Many basic facts concerning the structure and composition of matter are presented in Basic Electricity, NavPers 10086 (Series), and in Basic Electronics (in connection with the study of transistors). Study of these basic courses indicates that all matter is composed of atoms, and that these atoms are, in turn, composed of smaller subatomic particles.

The subatomic particles of major interest in elementary physics are the electron, the proton, and the neutron. They may be considered electrical in nature, with the proton representing a positive charge, the electron representing a negative charge, and the neutron being neutral (neither positive nor negative). Although in general the composition of matter follows a consistent pattern for all atoms, the detailed arrangement of subatomic particles is different for each distinct substance. It is the combination and arrangement of the subatomic particles which imparts the distinguishing chemical and physical characteristics to a substance.

The protons and the neutrons of an atom are closely packed together in a nucleus (core), with the electrons revolving around the nucleus. Atoms are normally considered to be electrically neutral—that is, they normally contain an equal number of electrons and protons; but this condition does not actually prevail under all circumstances. Atoms which contain an equal number of electrons and protons are called balanced atoms; those with an excess or a deficiency of electrons are called "ions."

The proton and the neutron have approximately the same mass, which is approximately 1,836 times the mass of an electron. In any atom, nearly all the mass is contained in the nucleus. It may be assumed that under normal conditions any change in the composition of the atom would involve a change in the number or arrangement of the electrons (due to the smaller mass, they are more easily repositioned). This assumption is generally correct—the most notable exception being in the field of nuclear physics, or nucleonics. In chemistry and in general physics (including electricity and electronics), it is the electron complement that is of major concern.

ELEMENT

The word element is used to denote any one of over 100 substances which comprise the basic substance of all matter. Two or more elements may combine chemically to form a compound; any combination which does not result in a chemical reaction between the different elements is called a mixture. The atom represents the smallest particle of an element. An atom of any one element differs from an atom of any other element in the number of protons

in the nucleus; all atoms of a given element contain the same number of protons. Thus, it may be seen that the number of protons in the nucleus determines the type of matter.

The various elements are frequently tabulated according to the number of protons. The number of protons in the nucleus of the atom is referred to as the atomic number of the element.

Nucleus

The study of the nucleus of the atom, known as nucleonics or nuclear physics, is the subject of extensive modern investigation. Experiments on nuclei usually involve the bombardment of the nucleus of an atom, using various types of nuclear particles. By this method the composition of the nucleus is changed, usually resulting in the release of energy. The change to the nucleus may occur as an increase or a decrease in the number of protons and/or neutrons.

If the number of protons is changed, the atom has become an atom of a different element. This process, called "transmutation," is the process sought by the alchemists of the middle ages in attempts to change various metals into gold. Scientists of that period believed transmutation could be accomplished by chemical means—hence the impetus given to the development of chemistry.

If, on the other hand, only the number of neutrons in the nucleus is changed, the atom remains an atom of the same element. Although though all the atoms of any particular element have the same number of protons (atomic number), atoms of certain elements may contain various numbers of neutrons. Hydrogen (the exception to the rule that all atoms are composed of three kinds of subatomic particles) normally contains a single proton and a single electron—and no neutrons. However, some hydrogen atoms do contain a neutron. Such atoms (although they are atoms of hydrogen) are known as deuterium, or "heavy hydrogen." (They are called "heavy" because the addition of the neutron has approximately doubled the weight of the atom. Deuterium figured prominently in the research which led to the development of nuclear energy and the atomic bomb.) The atomic weight of an atom is an indication of the total number of protons and neutrons in the atomic nucleus.

Atoms of the same element but which have different atomic weights are called isotopes. Nearly all elements have several isotopes; some are very common. and some are very rare. A few of the isotopes occurring naturally and most of these produced by nuclear bombardment are radioactive or have unstable nuclei. These unstable isotopes undergo a spontaneous nuclear bombardment which eventually results in either a new element or a different isotope of the same element. The rate of spontaneous radioactive decay is measured by "half-life," which is the time required for one-half of a sample of radioactive material to change (by spontaneous radioactive decay) into a different substance.

Electron Shells

The physical and chemical characteristics of an element are determined by the number and distribution of electrons in the atoms of that element. The electrons are arranged in successive groups of electron shells of rotation around the nucleus; each shell can contain no more than a specific number of electrons, as described in Basic Electronics. An INERT element (that is, an element which does not combine chemically with any other element) is a substance in which the outer electron shell of each atom is completely filled. In an element that is not chemically inert, one or more electrons are missing from the outer shell. An atom with only one or two electrons in its outer shell can be made to give up those electrons; an atom whose outer shell needs only one or two electrons to be completely filled can accept electrons from another element which has one or two "extras."

The concept of "needed" or "extra" electrons arises from the basic fact that all atoms have a tendency toward completion (filling) of the outer shell. An atom whose outer shell has only two electrons would have to collect six additional ones (no easy task, from an energy standpoint) in order to have the eight required for a full shell. A much easier way to achieve the same objective is to give up the two electrons in the outer shell and let the full shell next to it serve as the new outer shell. In chemical terminology, this concept is called valence, and is the prime determining factor in predicting chemical combinations.

COMPOUNDS AND MIXTURES

Under certain conditions, two or more elements can be brought together in such a way that they unite chemically to form a COMPOUND.

The resulting substance may differ widely from any of its component elements; for example, ordinary drinking water is formed by the chemical union of two gases—hydrogen and oxygen. When a compound is produced, two or more atoms of the combining elements join chemically to form the MOLECULE that is typical of the new compound. The molecule is the smallest unit that exhibits the distinguishing characteristics of a compound.

The combination of sodium and chlorine to form the chemical compound sodium chloride (common table salt) is a typical example of the formation of molecules. Sodium is a highly caustic poisonous metal containing eleven electrons; its outer shell consists of a single electron, which may be considered "extra" (a valence of +1). Chlorine, a highly poisonous gas with seventeen electrons, "lacks" a single electron (has a valence of -1) to fill its outer shell. When the atom of sodium gives up its extra electron, it becomes a positively charged ion. (It has lost a unit of negative charge.) The chlorine, having taken on this extra unit of negative charge (electron) to fill its outer shell, becomes a negative ion. Since opposite electric charges attract, the ions stick together to form a molecule of the compound sodium chloride.

The attracting force which holds the ions together in the molecular from is known as the "valence bond," a term which is frequently encountered in the study of transistors.

Note that in the chemical combination, there has been no change in the nucleus of either atom; the only change has occurred in the distribution of electrons between the outer shells of the atoms. Also note that the total number of electrons has not changed—there are still the twenty-eight of the original two atoms—although there has been a slight redistribution. Therefore, the molecule is electrically neutral, and has no resultant electrical charge.

Not all chemical combinations of atoms are on a one-for-one basis. In the case of drinking water, two atoms of hydrogen (valence of +1 are required to combine with a single atom of oxygen (valence of -2) to form a single molecule of water. Some of the more complex chemical compounds consist of many elements with various numbers of atoms of each. All molecules, like all atoms, are normally considered to be electrically neutral. There are some exceptions to this rule, however, with specific cases of interest being the chemical activity in batteries.

Elements or compounds may be physically combined without necessarily undergoing any chemical change. Grains of finely powdered iron and sulfur stirred and shaken together retain their own identify as iron or sulfur. Salt dissolved in water is not a compound; it is merely salt dissolved in water. Each chemical substance retains its chemical identity, even though it may undergo a physical change. This is the typical characteristic of a MIXTURE.

STATES OF MATTER

In their natural condition, forms of matter are classified and grouped in many different ways. One such classification is in accordance to their natural state--solid, liquid, or gas. This classification is important because of the common characteristics possessed by substances in one group which distinguish them from substances in the other groups. However, the usefulness of the classification is limited by the fact that most substances can be made to assume any of the three forms.

In all matter, the molecules are assumed to be in constant motion, and it is the extent of this motion that determines the state of matter. The moving molecular particles in all matter possess kinetic energy of motion. The total of this kinetic energy is considered to be the equivalent of the quantity of heat in a sample of the substance. When heat is added, the energy level is increased, and molecular agitation (motion) is increased. When heat is removed, the energy level decreases, and molecular motion diminishes.

In solids, the motion of the molecules is greatly restricted by the rigidity of the crystalline structure of the material. In liquids, the molecular motion is somewhat less restricted, and the substance as a whole is permitted to "flow." In gases, molecular motion is almost entirely random—the molecules are free to move in any direction and are almost constantly in collision both among themselves and with the surfaces of the container.

This topic and some of its more important implications are discussed in detail under the heading "Heat" in a later section of this chapter.

Solids

The outstanding characteristic of a solid is the tendency to retain its size and shape. Any change in these values require the exchange of

energy. The common properties of a solid are cohesion and adhesion, tensile strength, ductility, malleability, hardness, brittleness, and elasticity. Ductility is a measure of the ease with which the material can be drawn into a wire. Malleability refers to the ability of some materials to assume a new shape when pounded. Hardness and brittleness are self-explanatory terms. The remaining properties are discussed in more detail in the following paragraphs.

NOTE: Although these properties are common to solids, they vary to a large degree, depending upon the type of material. Therefore, they are primary factors to be considered when selecting material for a particular application. These properties, relative to the metals used in the structural members and components of support equipment, are discussed in more detail in chapter 6 of this training manual.

COHESION AND ADHESION.—Cohesion is the molecular attraction between like particles throughout a body, or the force that holds any substance or body together. Adhesion is the molecular attraction existing between surfaces of bodies in contact, or the force which causes unlike materials to stick together.

Cohesion and adhesion are possessed by different materials in widely varying degrees. In general, solid bodies are highly cohesive but only slightly adhesive. Fluids (liquids and gases), on the other hand, are usually quite highly adhesive but only slightly cohesive. Generally a material having one of these properties to a high degree will possess the other property to a relatively low degree.

TENSILE STRENGTH.—The cohesion between the molecules of a solid explains the property called tensile strength. This is a measure of the resistance of a solid from being pulled apart. Steel possesses this property to a high degree, and is thus very useful in structural work. When a break does occur, the pieces of the solid cannot be stuck back together because merely pressing them together does not bring the molecules into close enough contact to restore the molecular force of cohesion. However, melting the edges of the break (welding) allows the molecules on both sides of the break to flow together, thus bringing them once again into the close contact required for cohesion.

ELASTICITY.—If a substance will spring back to its original form after being deformed, it has the property of elasticity. This property is desirable in materials to be used as springs. Steel and bronze are examples of materials which exhibit this property.

Elasticity of compression is exhibited to some degree by all solids, liquids, and gases; the closeness of the molecules in solids and liquids makes them hard to compress, but gases are easily compressed because the molecules are farther apart.

Liquids

The outstanding characteristic of a liquid is its tendency to retain its own volume while assuming the shape of its container; thus a liquid is considered almost completely flexible and highly fluid.

Liquids are practically incompressible; applied pressure is transmitted through them instantaneously, equally, and undiminished to all points on the enclosing surfaces. Hydraulic apparatus can be used to increase or to decrease input forces, thus providing an action similar to that of mechanical advantage in mechanical systems. Because of these properties, hydraulic servomechanisms have advantages as well as disadvantages and limitations when compared with other servosystems.

The fluidity of hydraulic liquids permits the component parts of the system to be placed conveniently at widely separated points when necessary. Hydraulic power units can transmit energy around corners and bends without the use of complicated gears and levers. They operate with a minimum of slack and friction, which are often excessive in mechanical linkages. Uniform action is obtained without vibration, and the operation of the system remains largely unaffected by variations in load. The accumulator (which provides the necessary pressurization of the system to furnish practically instantaneous response) can be pressurized during periods of nonaction, thus eliminating the "buildup time" characteristic of electric servos.

The principles of hydraulics and pneumatics are discussed briefly in chapter 13. Fluid Power, NavPers 16193 (Series), contains detailed information concerning the physics of fluids (both liquids and gases) as applied to hydraulics and pneumatics.

Gases

The most notable characteristics of a gas are its tendency to assume not only the shape

but also the volume of its containers, and the definite relationship that exists between the volume, pressure, and temperature of a confined gas.

The ability of a gas to assume the shape and volume of its container is the result of its extremely active molecular particles, which are free to move in any direction. Cohesion between molecules of a gas is extremely small, so the molecules tend to separate and distribute themselves uniformly throughout the volume of the container. In an unpressurized container of liquid, pressure is exerted on the bottom and the sides of the container up to the level of the liquid. In a gas, however, the pressure is also exerted against the top surface, and the pressure is equal at all points on the enclosing surfaces.

The relationship of volume, pressure, and temperature of a confined gas are explained by Boyle's law, Charles' law, and the general law for gases.

Many laboratory experiments based on these laws make use of the ideas of "standard pressure" and "standard temperature." These are not natural standards, but are standard values selected for convenience in laboratory usage. Standard values are generally used at the beginning of an experiment, or when a temperature or a pressure is to be held constant. Standard temperature is 0°C, the temperature at which pure ice melts. Standard pressure is the pressure exerted by a column of mercury 760 millimeters high. In many practical uses these standards must be changed to other systems of measurement.

All calculations based on the laws of gases make use of "absolute" temperature and pressure. These topics require a somewhat more detailed explanation.

GAS PRESSURE.—Gas pressure may be indicated in either of two ways—absolute pressure or gage pressure. Since the pressure of an absolute vacuum is zero, any pressure measured with respect to this reference is referred to as "absolute pressure." In the present discussion, "absolute pressure" represents the actual pressure exerted by the confined gas.

At sea level the average atmospheric pressure is approximately 14.7 pounds per square inch (psi). This pressure would, in a mercurial barometer, support a column of mercury 760 millimeters in height. Thus, normal atmospheric pressure is the standard pressure mentioned previously.

However, the actual pressure at sea level varies considerably; and the pressure at any given altitude above sea level differs from that at sea level. Therefore, it is necessary to take into consideration the actual atmospheric pressure when converting absolute pressure to gage pressure (or vice versa).

When a pressure is expressed as the difference between its absolute value and that of the local atmospheric pressure, the measurement is designated "gage" pressure, and is usually expressed in "pounds per square inch gage" (psig). Gage pressure may be converted to absolute pressure by adding the local atmospheric pressure to the gage pressure.

ABSOLUTE ZERO.—Absolute zero, one of the fundamental constants of physics, is usually expressed in terms of the Celsius scale. Its most predominant use is in the study of the kinetic theory of gases. In accordance with the kinetic theory, if the heat energy of a given gas sample could be progressively reduced, some temperature should be reached at which the motions of the molecules would cease entirely. If accurately determined, this temperature could then be taken as a natural reference, or a true "absolute zero" value.

Experiments with hydrogen (making use of the proven correlation with the volume, temperature, and pressure of gases and by calculations based on this correlation) indicated that if a gas were cooled to -273.16°C (used as -273° for most calculations), all molecular motion would cease and no additional heat could be extracted from the substance. At this point both the volume and the pressure would shrink to zero.

When temperatures are measured with respect to the absolute zero reference, they are said to be expressed in the absolute, or Kelvin, scale. Thus, absolute zero may be expressed either as 0°K or as -273°C.

BOYLE'S LAW.—The English scientist Robert Boyle was among the first to study what he called the "springiness of air." By direct measurement he discovered that when the temperature of an enclosed sample of gas was kept constant and the pressure doubled, the volume was reduced to half the former value; as the applied pressure was decreased, the resulting volume increased. From these observations, he concluded that for a constant temperature the product of the volume and pressure of an enclosed gas remains constant. Boyle's law is normally stated: "The volume of an enclosed

dry gas varies inversely with its pressure, provided the temperature remains constant."

In equation form, this relationship may be expressed either

$$V_1P_1 = V_2P_2, \text{ or}$$

$$\frac{V_1}{V_2} = \frac{P_2}{P_1}$$

where V_1 and P_1 are the original volume and pressure, and V_2 and P_2 are the revised volume and pressure.

CHARLES' LAW.—The French scientist Jacques Charles provided much of the foundation for the modern kinetic theory of gases. He found that all gases expand and contract in direct proportion to the change in the absolute temperature, provided the pressure is held constant. Expressed in equation form, this part of the law may be expressed

$$V_1T_2 = V_2T_1, \text{ or}$$

$$\frac{V_1}{V_2} = \frac{T_1}{T_2}$$

where V_1 and V_2 refer to the original and final volumes, and T_1 and T_2 indiçate the corresponding absolute temperatures.

Since any change in the temperature of a gas causes a corresponding change in volume, it is reasonable to expect that if a given sample of a gas were heated while confined within a given volume, the pressure should increase. By actual experiment, it was found that the increase in pressure was approximately 1/273 of the 0°C pressure for each 1°C increase. Because of this fact, it is normal practice to state this relationship in terms of absolute temperature. In equation form, this part of the law becomes

$$P_1T_2 = P_2T_1, \text{ or}$$

$$\frac{P_1}{P_2} = \frac{T_1}{T_2}$$

In words, this equation states that with a constant volume, the absolute pressure of a gas varies directly with the absolute temperature.

GENERAL GAS LAW.—The facts concerning gases discussed in the preceding sections are summed up and illustrated in figure 3-2. Boyle's law is expressed in (A) of the figure; while the effects of temperature changes on pressure and volume (Charles' law) are illustrated in (B) and (C), respectively.

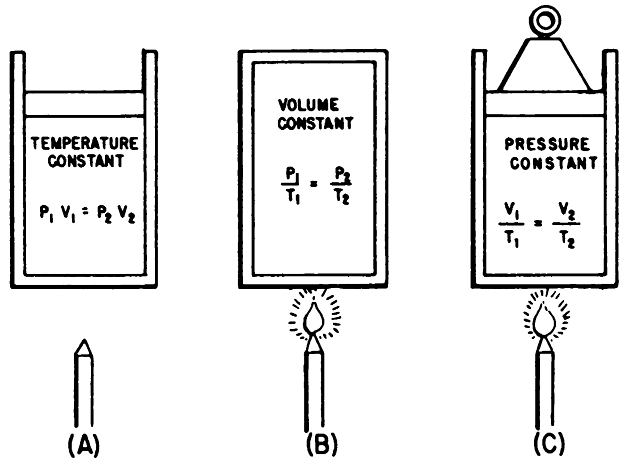


Figure 3-2.—The general gas law.

By combining Boyle's and Charles' laws, a single expression can be derived which states all the information contained in both. This expression is called the GENERAL GAS EQUATION, a very useful form of which is given by the following equation. (NOTE: The capital P and T signify absolute pressure and temperature, respectively.)

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

It can be seen by examination of figure 3-2 that the three equations are special cases of the general equation. Thus, if the temperature remains constant, T_1 equals T_2 and both can be eliminated from the general formula, which then reduces to the form shown in (A). When the volume remains constant, V_1 equals V_2, thereby reducing the general equation to the form given in (B). Similarly, P_1 is equated to P_2 for constant pressure, and the equation then takes the form given in (C).

The general gas law applies with exactness only to "ideal" gases in which the molecules are assumed to be perfectly elastic. However, it describes the behavior of actual gases with sufficient accuracy for most practical purposes.

MECHANICS

Mechanics is that branch of physics which deals primarily with the ideas of force, mass, and motion. Normally considered the fundamental branch of physics, it deals with matter. Many of its principles and ideas may be seen, measured, and tested. Since all other branches of physics are also concerned (to some extent at least) with force, mass, and motion, a thorough understanding of this section will aid in the understanding of later sections of this chapter.

FORCE, MASS, AND MOTION

Each particle in a body is acted upon by gravitational force. However, in every body there is one point at which a single force, equal to the gravitational force and directed upward, would sustain the body in a condition of rest. This point is known as the CENTER OF GRAVITY, and represents the point at which the entire mass of the body appears to be concentrated. The gravitational effect is measured from the center of gravity. In symmetrical objects of uniform mass, this is the geometrical center. In the case of the earth, the center of gravity is near the center of the earth.

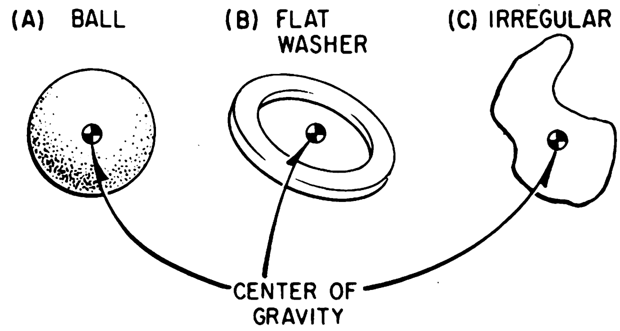
Then considering the motion of a body, it is usually convenient to describe the path followed by the center of gravity. The natural tendency of a moving body is to move in a manner so that the center of gravity travels in a straight line. Movement of this type is called LINEAR motion.

Some moving bodies, however, do not move in a straight line, but describe an arc or a circular path. Circular motion falls into two general classes—rotation and revolution.

Since objects come in many different shapes and in order to discuss rotary and revolutionary motion, it becomes necessary to consider the location of the center of gravity with respect to the body. (Refer to figure 3-3 for the following discussion.)

In (A), the center of gravity of a ball coincides with the physical center of the ball. However, in the flat washer (B), the center of gravity does not coincide with any part of the object, but is located at the center of the hollow space inside the ring. In irregularly shaped bodies, the center of gravity may be difficult to locate exactly.

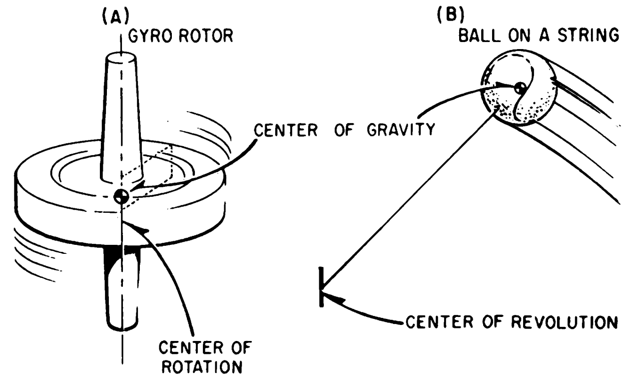
If the body is completely free to rotate, the center of rotation coincides with the center of



AT.22

Figure 3-3.—Center of gravity in various bodies.

gravity. On the other hand, the body may be restricted in such a manner that rotation is about some point other than the center of gravity. In this event, the center of gravity revolves around the center of rotation. This condition is illustrated in figure 3-4.



AT.23

Figure 3-4.—Center of gravity and center of rotation.

In general usage, the gyro rotor (A) is said to ROTATE about its axis, and the ball (B) is said to REVOLVE about a point at the center of its path.

MASSES IN MOTION

Any change in the speed or direction of motion of a body is known as acceleration and requires the application of some force. The

acceleration of a body is directly proportional to the force causing that acceleration; acceleration depends also upon the mass of the body. The greater mass of a lead ball makes it harder to move than a wood ball of the same diameter. The wood ball moves farther with the same push.

These observations point to a connection between force, mass, and acceleration, and indicate that the acceleration of a body is directly proportional to the force exerted on that body and inversely proportional to the mass of that body. In mathematical form, this relationship may be expressed as

$$a = \frac{F}{m}$$

or, as it is more commonly stated: Force is equal to the product of the mass and acceleration ($F = ma$).

If the accelerating force is applied to the center of gravity in such a manner as to accelerate the body with no rotation, it is called a TRANSLATIONAL force. A force applied in such a manner as to cause the body to rotate about a point is called a TORQUE force. For example, a hydraulic piston type actuating cylinder provides linear or reciprocating motion, while a hydraulic motor provides rotary motion. Therefore, the force provided by the piston type actuating cylinder is translational force and that provided by the motor is torque force.

Laws of Motion

Among the most important discoveries in theoretical physics are the three fundamental laws of motion attributed to Newton. Although some of these laws have been used in explanations of various topics earlier in this chapter, they are restated and consolidated at this point to clarify and summarize much of the discussion regarding mechanical physics. This restatement and consolidation are also used to introduce additional aspects involving the applications of basic mechanical principles.

1. Every body tends to maintain a state of uniform motion unless a force is applied to change the speed or direction of motion.

2. The acceleration of a body is directly proportional to the magnitude of the applied force and inversely proportional to the mass of the body; acceleration is in the direction of the applied force.

3. For every force applied to a body, the body exerts an equal force in the opposite direction.

Momentum

Every moving body tends to maintain uniform motion. Quantitative measurement of this tendency is proportional to the mass of the body, and also to its velocity. (Momentum = mass x velocity.) This explains why heavy objects in motion at a given speed are harder to stop than lighter objects, and also why it is easier to stop a given body moving at low speed than it is to stop the same body moving at high speed.

WORK, POWER, AND ENERGY

As defined earlier, energy is the capacity for doing work. In mechanical physics, WORK involves the idea of a mass in motion, and is usually regarded as the product of the applied force and the distance through which the mass is moved (work = force x distance). Thus, if a man raises a weight of 100 pounds to a height of 10 feet, he accomplished 1,000 foot-pounds of work. The amount of work accomplished is the same regardless of the time involved. However, the RATE of doing the work may vary greatly.

The rate of doing work (called POWER) is defined as the work accomplished per unit of time (power = work/time). In the example cited above, if the work is accomplished in 10 seconds, power is being expended at the rate of 100 foot-pounds per second; if it takes 5 minutes (300 seconds), the rate is approximately 3.3 foot-pounds per second.

In the English system of measurements, the unit of mechanical power is called the HORSEPOWER and is the equivalent of 33,000 foot-pounds per minute, or 550 foot-pounds per second. Since energy is readily convertible from one form to another, the work and power measurements based on the conversion of energy must also be readily convertible. As an example, the electrical unit of power is the watt. Electrical energy may be converted into mechanical energy; therefore, electrical power must be convertible into mechanical power. One horsepower is the mechanical equivalent of 746 watts of electrical power, and is capable of doing the same amount of work in the same time.

The accomplishment of work always involves a change in the type of energy, but does not normally change the total quantity of energy. Thus, energy applied to an object may produce work, changing the composition of the energy possessed by the object. When the work stops, energy is no longer being "expended," so energy must once again be converted in form—but not necessarily into its original form.

Efficiency

Provided there is no change in the quantity of matter, energy is convertible with no gain or loss. However, the energy resulting from a given action may not be in the desired form—it may not even be usable in its resultant form. In all branches of physics, this concept is known as EFFICIENCY.

The energy expended is always greater than the energy recovered. An automobile in motion possesses a quantity of kinetic energy dependent on its mass and velocity. In order to stop the car, this energy must be converted into potential energy. When the car is at rest, its potential energy is considerably less than the kinetic energy it possessed while in motion. The difference, or the "energy lost," is converted into heat by the brakes. The heat serves no useful purpose, so the recovered energy is less than the expended energy—the system is less than 100 percent efficient in converting kinetic to potential energy.

The term efficiency is normally used in connection with work and power considerations to denote the ratio of the input to the output work, power, or energy. It is always expressed as a decimal or as a percent less than unity.

Friction

In mechanical physics, the most common cause for the loss of efficiency is FRICTION. Whenever one object is slid or rolled over another, irregularities in the contacting surfaces interlock and cause an opposition to the force being exerted. Even rubbing two smooth pieces of ice together produces friction, although of a much smaller magnitude than in the case of two rough stones. Friction also exists in the contact of air with all exposed parts of an aircraft in flight, as well as in the brakes of the automobile mentioned above.

When a nail is struck with a hammer, the energy of the hammer is transferred to the nail, and the nail is driven into a board. The depth of penetration depends on the momentum of the hammer, the size and shape of the nail, and the hardness of the wood. The larger or duller the nail and the harder the wood, the greater the friction, and therefore the lower the efficiency and less depth of penetration—but the greater the heating of the nail.

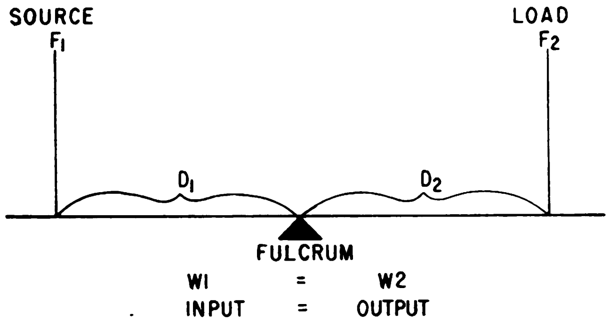
Friction is always present in moving machinery, and accounts in part for the fact that the useful work accomplished by the machine is never as great as the energy applied. Work accomplished in overcoming friction is usually not recoverable. Friction can be minimized by decreasing the number of contacting points, by making the contacting areas as small and as smooth as possible, by the use of bearings, or by the use of lubricants.

There are two kinds of friction—sliding and rolling, with rolling friction usually of lower magnitude. Therefore, most machines are constructed so that rolling friction is present rather than sliding friction. The ball bearing and the roller bearing are used to convert sliding friction to rolling friction. A third type, the common (or friction) bearing, utilizes lubricants applied to surfaces which have been made as smooth as possible. Many new types of machines utilize self-lubricating bearings to minimize friction and thus increase efficiency.

Mechanical Advantage

The concept of mechanical advantage has proved to be one of the great discoveries of science. It permits an increase in force or distance and represents the basic principle involved in levers, block and tackle systems, screws, hydraulic mechanisms, and other work saving devices. However, in the true sense, these devices do not save work, they merely enable humans to accomplish tasks which might otherwise be beyond their capability. For example, a human would normally be considered incapable of lifting the rear end of a truck in order to change a tire; but with a jack, a block and tackle, or a lever, the job can be made comparatively easy.

Mechanical advantage is usually considered with respect to work. Work represents the application of a force through a distance in order to move an object through a distance. Thus, it may be seen that there are two forces involved, each with an appropriate distance. This is illustrated by the simple lever in figure 3-5.



AT.24
Figure 3-5.—Mechanical advantage.

Assuming perfect efficiency, the work input (F_1D_1) is equal to the work output (F_2D_2). Assuming equal distances D_1 and D_2, a force of 10 pounds must be applied at the source in order to counteract a weight of 10 pounds at the load. By moving the fulcrum nearer the load, less force is required to balance the same load. This is a mechanical advantage of force. If the force is applied in such a manner as to raise the load 1 foot, the source must be moved through a distance greater than 1 foot. Thus, mechanical advantage of force represents a mechanical disadvantage of distance. By moving the fulcrum nearer the source, these conditions are reversed.

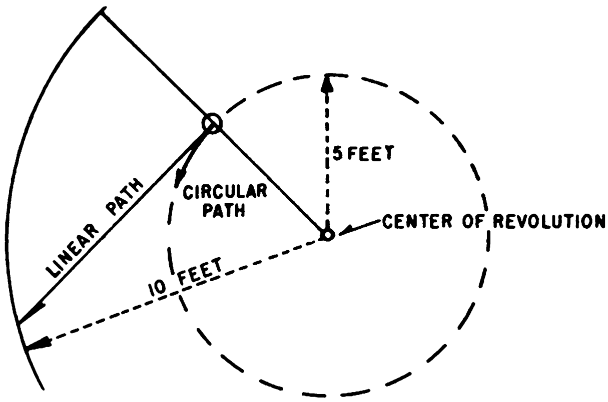
Since the input work equals the output work (assuming no losses), the mechanical advantage may be stated as a ratio of the force or of the distances. In actual situations, friction results in energy loss and decreased efficiency, thereby requiring an even greater input to accomplish the same work.

A more detailed discussion of mechanical advantages and the characteristics of the six basic mechanical devices (the lever, the screw, the inclined plane or wedge, the block and tackle, the wheel and axle, and the gear) is found in the Rate Training Manual, Basic Machines, NavPers 10624 (Series).

REVOLVING BODIES

Revolving bodies represent masses in motion; therefore, they possess all the characteristics (and obey all the laws) associated with moving bodies. In addition, since they possess a specific type of motion, they have special properties and factors which must be taken into consideration.

Revolving bodies travel in a constantly changing direction, so they must be constantly subjected to an accelerating force. Momentum tends to produce linear motion, but this is prevented by application of a force which restrains the object. This restraining force prevents the object from continuing in a straight line, and is known as CENTRIPETAL force. According to Newton's third law of motion, the centripetal force must be opposed by an equal force which tends to produce linear motion. This second force is known as CENTRIFUGAL force. The two forces, their relationships, and their effects are illustrated in figure 3-6 and the following explanatory example.



AT.25
Figure 3-6.—Forces on revolving bodies.

The various forces involved in revolving bodies may be illustrated by use of a ball and string. A slip knot is tied in the center of a 10-foot length of twine so as to shorten the line to 5 feet; a rubber ball is attached to one end of the string. Holding the other end of the line, whirl the ball slowly in a circle. Note that the ball exerts a force against the hand (through the string); and that in order to restrain the ball in its circular path, the hand must exert a force (through the string) on the ball. As the ball is revolved at higher speed, the forces increase, and the ball continues in a circular path. As the rotational velocity of the ball is gradually increased, note the increasing forces.

At some rotational speed, the forces involved become great enough to overcome inertial friction, and the knot slips. At this time, allow the velocity of the rotation to stabilize (stop increasing in rotational velocity, but not slowing down, either), so that the existing conditions may be analyzed. When the knot slips, the ball is temporarily unrestrained and is free to assume linear motion in the direction of travel at that instant (tangent to the circle at the instantaneous position). The ball travels in a straight line until the string reaches its full length; during this time, no force is exerted on or by the hand. As soon as all the slack is taken up, there is a sharp jerk—an accelerating force is exerted in order to change the direction of motion from its linear path into a circular rotation. The ball again assumes rotational motion, but with an increase in radius.

The ball does not make as many revolutions in the same time (rotational velocity is decreased), but it does maintain its former linear velocity. (The kinetic energy and the momentum of the ball have not changed.) Since the change in direction is less abrupt with a large radius than with a small one, less accelerating force is required, and the hand will feel less force. If the ball is then accelerated to the same rotational velocity as immediately prior to the slipping of the knot, the linear velocity of the ball becomes much greater than before; the centripetal and centrifugal forces are also greater.

In this example, it has been assumed that the hand is fixed at a point which represents the center of rotation. This assumption, while somewhat erroneous, does not affect the general conclusions. For practical purposes, the two forces are equal at all points along the string at any given time, and the magnitude of each force is equal at all points along the string.

In summarizing the conclusions reached by the above example and explanation, consider the following relationship:

$$\text{force} = \frac{\text{weight x velocity}^2}{\text{radius}}$$

where velocity represents the linear velocity of the ball. This emphasizes that the centripetal and the centrifugal forces are equal in magnitude and opposite in direction. Each force is directly proportional to the weight of the body and inversely proportional to the radius of rotation. Each force is also proportional to the square of the velocity.

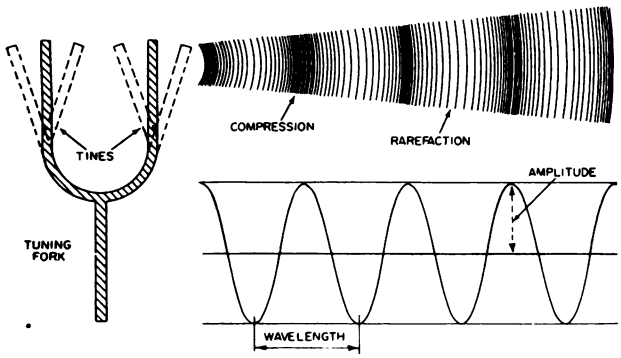
In revolving or rotating bodies, all particles of the matter which are not on the axis of rotation are subjected to the forces just described. The statement is true whether the motion is through a complete circle, or merely around a curve: An aircraft tends to skid when changing course; an automobile tends to take curves on two wheels. The sharper the curve (smaller radius) or the higher the velocity, the greater the tendency to skid.

WAVE MOTION

Wave motion and radiated energy may be compared with the wave motion of water. When a pebble is dropped into a calm pool of water, a series of circular waves travel away from the disturbance. These waves radiate in all directions on the surface of the water until they are absorbed or until they are diverted by coming into contact with an obstruction of some sort. Water waves are a succession of crests and troughs; the distance from one point to the next identical point on the wave is called wavelength. A cork floating on the surface of the water bobs up and down with the waves, but moves very little in the direction of wave travel. Water waves are called transverse waves because the motion of the water particles is up and down, or at right angles (transverse) to the direction in which the wave is traveling.

A second form of wave motion, also involving the motion of particles of matter, may be produced by the physical vibration of a body. An example of this type wave is the sound wave which is produced by striking the tine of a tuning fork. When struck, the tuning fork sets up a vibratory motion. As the tine moves in an outward direction, the air immediately in front of the tine is compressed so that its momentary pressure is raised above that at other points in the surrounding medium. Because air is elastic, this disturbance is transmitted progressively in an outward direction as a compression wave. When the tine returns and moves in the inward direction, the air in front of the tine is rarefied so that its momentary pressure is reduced below that at other points in the surrounding medium. This disturbance is also transmitted, but in the form of a rarefaction (expansion) wave, and follows the compression wave through the medium.

The compression and expansion waves are also called longitudinal waves, because the particles of matter which comprise the medium move back and forth longitudinally in the direction of wave travel. Figure 3-7 is a simplified representation of the use of a tuning fork to produce a longitudinal wave. The transverse wave shown below the longitudinal wave is merely a convenient device to indicate the relative density of the particles in the medium, and does not reflect the movement of the particles.



AT.26

Figure 3-7.—Compression and rarefaction (expansion) of a sound wave.

The progress of any wave requiring movement of particles in the transmission medium involves two distinct motions: the wave itself moves forward with constant speed, and simultaneously the particles within the medium vibrate. The period of a vibrating particle is the time (t, in seconds) required for the particle to complete one full vibration or cycle. The frequency (f) is the number of vibrations completed per unit of time and is usually expressed in hertz. The period is the reciprocal of the frequency ($t = 1/f$). The amplitude of vibration is the maximum variation of particle density from the equilibrium density.

A body vibrating at a definite rate produces a disturbance that moves away as a wave in the surrounding medium. The velocity of this wave is equal to the wavelength divided by the period. Since the period is the reciprocal of the frequency, the velocity may be expressed as

$$v = f\lambda$$

where v is the velocity of transmission of the wave in the given medium, f is the frequency in hertz, and λ is the wavelength in compatible units of measure. The velocity of transmission may also be described as representing the distance that a wave travels during one period.

Two particles are in phase when they are vibrating with the same frequency, and continually pass through corresponding points of their paths at the same time. For any other condition, the particles are out of phase. Two particles are in phase opposition when they reach their maximum displacements in opposite directions at the same time.

A third type of wave, the electromagnetic wave, does not involve moving particles of matter, but rely on electric and magnetic force fields. The waves previously discussed cannot be transmitted in the absence of a conducting medium—electromagnetic waves are transmitted most efficiently in the absence of matter. In the electromagnetic wave, two components are required—an electric field and a magnetic field. These two fields are mutually perpendicular to each other and to the direction of transmission. In the particle waves, the velocity of transmission varies with the particular medium, and is comparatively very slow; in the electromagnetic wave, the velocity of transmission is the speed of light (approximately 186,300 miles per second). Examples of electromagnetic waves include heat, light, radio waves, X-rays, cosmic radiations, ultraviolet rays, etc.

All three types of wave motion obey certain common laws and have certain common characteristics: All are periodic; that is, they all constantly repeat the same pattern so that each succeeding wave is the same as the previous one. Each wave displays the same relationships of wavelength, frequency, period, velocity of transmission, amplitude, and phase; and each is subject to the same conditions of reflection and refraction. In the electromagnetic wave, the maxima and minima are correlated with field intensity rather than with particle density or displacement as in the case of the other waves. In the longitudinal wave, the density is related to particle density; in the electromagnetic wave, density is related to the strength of the electric and magnetic fields. In the electromagnetic wave, the elecrtic field and the magnetic field are in phase with each other.

A wavelength (a complete cycle) is the distance from one point to the next identical point on the wave. (See fig. 3-7.) The wavelength could start at any point but is usually started on the axis.

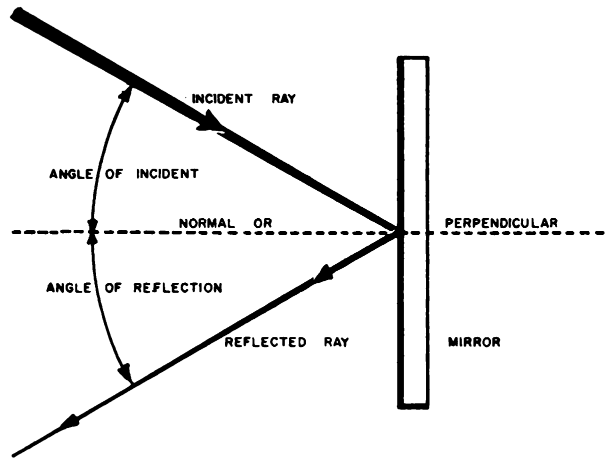
A line drawn from the source to any point on one of the waves is called a RAY, and indicates the path over which the wave progresses. Although rays do not actually exist, they are frequently used in illustrations as a convenient method of denoting wave transmission. A wavefront is a surface on which all points are in phase. Wavefronts near the source are sharply curved, while those at a distance are almost flat; individual rays from a distant source are considered to be parallel.

REFLECTION

Within a uniform medium, a ray travels in a straight line. Only at the boundary of two media or in an area where the density of the medium changes do the rays change their direction. When an advancing wavefront encounters a medium of different characteristics, some of its energy is reflected back into the initial medium, and some is transmitted into the second medium. When a wavefront encounters a medium which it cannot penetrate, the wave is reflected from the surface.

REFLECTED waves are simply those waves that are neither transmitted nor absorbed, but are thrown back from the surface of the medium they encounter. If a ray is directed against a reflecting surface, the ray striking the surface is called the INCIDENT ray, and the one that bounces back is the REFLECTED ray. An imaginary line perpendicular to the reflecting surface at the point of impact of the incident ray is called the NORMAL. The angle between the incident ray and the normal is called the ANGLE OF INCIDENCE; the angle between the reflected ray and the normal is the ANGLE OF REFLECTION. These terms are illustrated in figure 3-8.

If the surface of the medium contacted by the incident ray is smooth and polished (as a mirror), each reflected ray will be thrown back at the same angle as the incident ray. The path of the ray reflected from the surface forms an angle exactly equal to the one formed by its path in reaching the medium. This conforms to the law of reflection which states: The angle of incidence is equal to the angle of reflection.



AT.27

Figure 3-8.—Terms used to describe the reflection of waves.

Diffusion

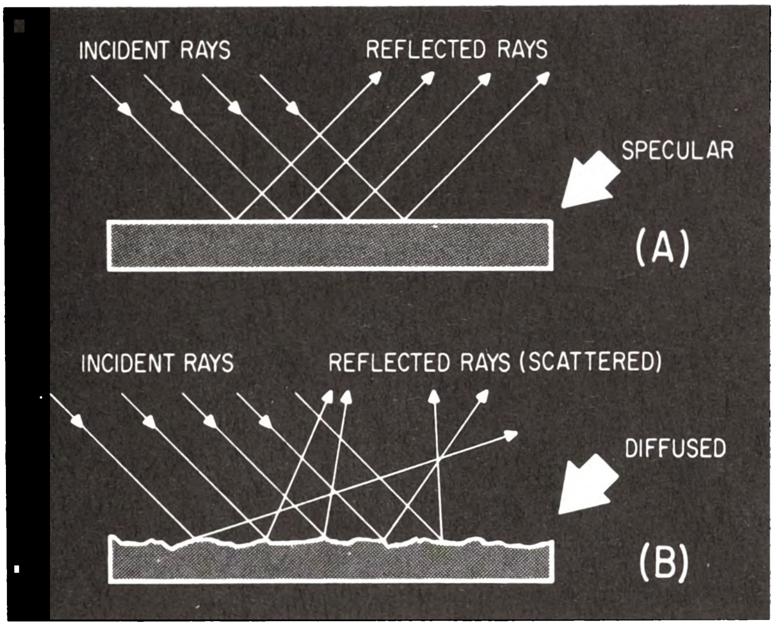
Reflection from a relatively smooth surface presents few problems. As shown in figure 3-9(A), rays are reflected from a flat smooth surface in an orderly manner with all rays at the same angle and all rays parallel to each other. This is called regular or specular reflection. It is a different matter, however, with a rough surface. The law of reflection is still valid; but due to the rough surface, the angle of incidence is somewhat different for each ray. The reflected rays scatter in all directions, as shown in figure 3-9(B). This form of reflection is called irregular or diffused reflection.

Focusing

In addition to reflection from a flat surface and diffusion from a rough one, waves may also be focused by reflection from a curved surface. If the reflecting surface is concave, the parallel rays striking its surface are reflected, as shown in figure 3-10(A). The normal is perpendicular to the surface; therefore, the normals on a curved surface are not parallel to one another. The rays come together, or converge, at some point called the focal point. The location of the focal point depends on the rate of curvature of the reflecting surface.

Illumination

If a point source of waves is located at the focal point of the concave reflector, the reflected rays are formed into a narrow beam,



AT.28
Figure 3-9.—Reflection from a plane surface. (A) Regular (specular); (B) irregular (diffused).

with all reflected rays parallel to one another. This condition is illustrated in figure 3-10(B). In this manner, the intensity is increased (or the area is "illuminated"), because rays that would normally be lost are directed into the beam along with the direct rays.

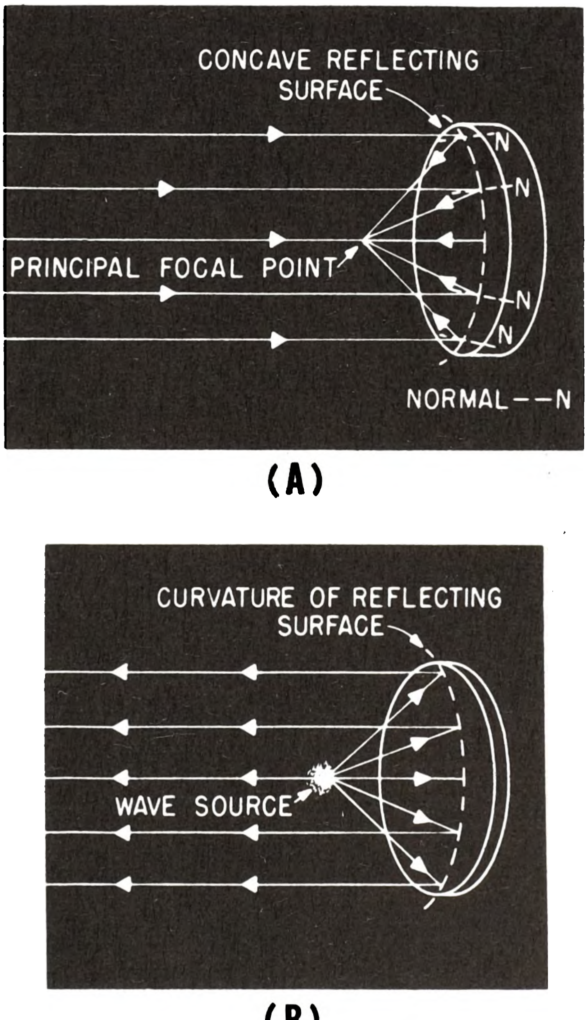
REFRACTION

The change of direction which occurs when a ray passes from one medium into another of different density is called REFRACTION. It is due to the fact that waves travel at various speeds in different transmission media. Refraction always follows a general rule: When a ray passes from one medium into another of greater density, refraction is toward the normal; when passing into a medium of lesser density, refraction is away from the normal. This is illustrated in figure 3-11.

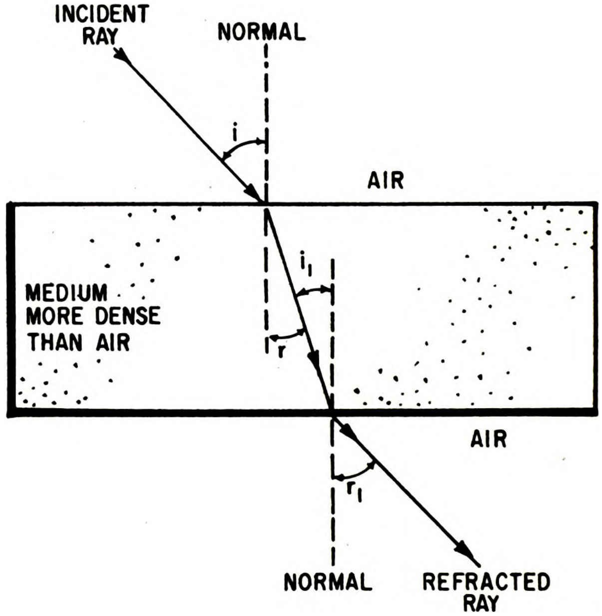
HEAT

Heat represents a form of energy; therefore, it must be readily exchangeable with or convertible into other forms of energy. The conversion of mechanical energy into heat through friction has been mentioned previously. When a piece of lead is struck a sharp blow with a hammer, part of the kinetic energy of the hammer is converted into heat. In the core of a transformer, electrical and magnetic energy are exchanged; but due to hysteresis and eddy currents, some of the energy is lost as heat. These are some examples of the unwanted conversions, but there are many instances when the production of heat is desirable. Many devices are used almost exclusively to produce heat.

Regardless of how or why it is produced, heat possesses certain characteristics which make it important to the ASH. A knowledge of the nature and behavior of heat is necessary in understanding welding and cutting of metals, discussed in chapters 7, 8, and 9. This knowledge may also prove helpful in undertsanding the dissipation of heat from brakes, hydraulic fluids, internal combustion engines, air compressors, etc. Heat dissipation is also a major factor in understanding the operation of air-conditioning units. Although the maintenance of these units is the responsibility of the ASM and ASE service ratings, remember that the ASH2 must have a thorough knowledge of the ASM and ASE specialties for advancement to AS1.



AT.29
Figure 3-10.—Reflection from a concave surface. (A) Focusing; (B) illumination.



AT.30
Figure 3-11.—Refraction of a wave.

NATURE OF HEAT

There are several theories regarding the nature of heat, none of which satisfactorily explain all the characteristics and properties exhibited by heat. The two theories most commonly included in discussions regarding the nature of heat are the kinetic theory and the radiant energy theory.

In the kinetic theory (mentioned earlier in this chapter), it is assumed that the quantity of heat contained by a body is represented by the total kinetic energy possessed by the molecules of the body.

The radiation theory treats radio waves, heat, and light as the same general form of energy, differing primarily in frequency. Heat is considered as a form of electromagnetic energy involving a specific band of frequencies falling between the radio spectrum and light.

A common method used to produce heat energy is the burning process. Burning is a chemical process in which the fuel unites with oxygen, and a flame is usually produced. The amount of heat liberated per unit mass or per unit volume during complete burning is known as the heat of combustion of a substance. By experiment, scientists have found that each fuel produces a given amount of heat per unit quantity burned.

TRANSFER

There are three methods of heat transfer—conduction, convection, and radiation. In addition to these, a phenomenon called absorption is related to the radiation method.

Conduction

The metal handle of a hot pot may burn the hand; a plastic or wooden handle, however, remains relatively cool even though it is in direct contact with the pot. This phenomenon is due

to a property of matter known as thermal conductivity. All materials conduct heat—some very readily, some to an almost negligible extent. When heat is applied to a body, the molecules at the point of application become violently agitated, strike the molecules next to them, and cause increased agitation. The process continues until the heat energy is distributed evenly throughout the material. Aluminum and copper are used for cooking pots because they conduct heat very readily to the food being cooked. Wood and plastic are used as handles because they are very poor conductors of heat. As a general rule, metals are the best conductors of heat, although some metals are considerably better than others. For example, cast iron is a better heat conductor than steel. For this reason, steel brake drums contain a cast iron liner. The steel provides the strength and the cast iron provides the necessary heat dissipating qualities. Brake drums are described in more detail in chapter 15.

Among solids, there is an extreme range of thermal conductivity. In the original example, the metal handle transmits heat from the pot to the hand, with the possibility of burns. The wooden or plastic handle does not conduct heat very well, so the hand is given some protection. Materials that are extremely poor conductors are called "insulators" and are used to prevent heat transfer. Some examples are the wood handle of soldering irons, the finely spun glass or rock wool insulation in houses, or the asbestos tape or ribbon wrapping used on steam pipes.

Liquids are generally poorer conductors than metals. In figure 3-12 note that the ice in the bottom of the test tube has not yet melted, although the water at the top is boiling. Water is such a poor conductor that the rate of heating the water at the top of the tube is not sufficient to cause rapid melting of the ice at the bottom.

Since thermal conduction is a process by which molecular energy is passed on by actual contact, gases are generally even poorer conductors than liquids because the molecules are farther apart and molecular contact is not so pronounced.

Convection

Convection is the process in which heat is transferred by movement of a hot fluid (gas or liquid). For example, an air compressor in operation becomes hotter and hotter until the

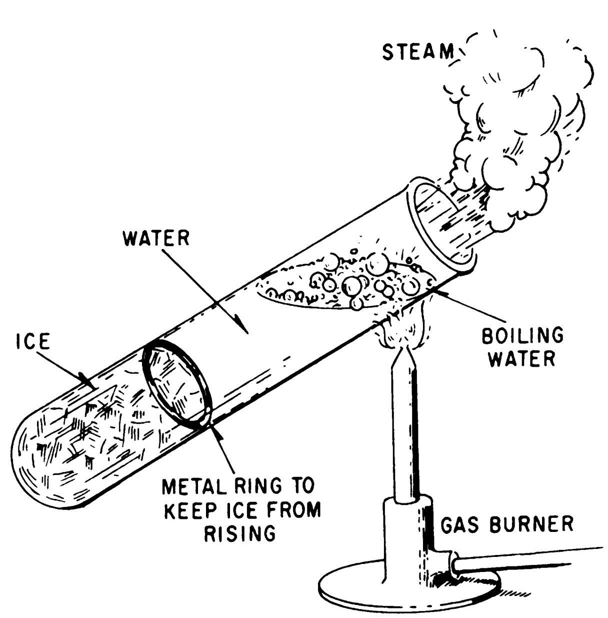


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Figure 3-12.—Water is a poor conductor of heat.

air surrounding it begins to move. The motion of the air is upward because heated air expands in volume and is forced upward by the denser cool air surrounding it. The upward motion of the heated air carries the heat away from the air compressor by convection. Transfer of heat by convection may be hastened by using a ventilating fan to move the air surrounding a hot object. The rate of cooling of an air compressor is increased by finned tubing (inter-aftercoolers) between each stage of compression. The fins provide large surfaces against which cool air can be blown, thus cooling the compressed air as it flows through the tubing. Air compressors are described in chapter 13.

A convection process may take place in a liquid as well as in a gas. One example is a transformer oil bath. The hot oil is less dense (has less weight per unit volume) and rises, while the cool oil falls, is heated, and rises in turn.

When the circulation of gas or liquid is not rapid enough to remove sufficient heat, fans or pumps may be used to accelerate the motion of the cooling material. In some installations, pumps are used to circulate water or oil to help cool large equipment. Fans and blowers are sometimes used to aid convection.

An internal combustion engine is cooled in this manner. Water is circulated around the engine. This removes the heat from the engine. The water then flows through the radiator where it is cooled. The air provided by the moving vehicle and the fan forces air through the honeycomb radiator, thus removing heat from the water. A pump is provided to circulate the water through the system.

Radiation

Conduction and convection cannot wholly account for some of the phenomena that are associated with heat transfer. For example, heating through convection cannot occur in front of an open fire because the air currents are moving toward the fire. It cannot occur through conduction because the conductivity of the air is very low, and the cooler currents of air moving toward the fire would more than overcome the transfer of heat outwardly. Therefore, heat must travel across space by some means other than conduction and convection.

The existence of another process of heat transfer is still more evident when the heat from the sun is considered. Since conduction and convection take place only through molecular contact within some medium, heat from the sun must reach the earth by some other method. (Outer space is an almost perfect vacuum.) Radiation is the name given to this third method by which heat travels from one place to another.

The term radiation refers to the continual emission of energy from the surface of all bodies. This energy is known as radiant energy. It is in the form of electromagnetic waves and is identical in nature with light waves, radio waves, and X-rays, except for a difference in wavelength. Sunlight is a form of radiant heat energy which travels great distances through cold, empty space to reach the earth. These electromagnetic heat waves are absorbed when they come in contact with nontransparent bodies. The net result is that the motion of the molecules in the body is increased, as indicated by an increase in the temperature of the body.

The differences in conduction, convection, and radiation are as follows:

1. Although conduction and convection are extremely slow, radiation takes place with the speed of light. This fact is evident at the time of an eclipse of the sun when the shutting off of the heat from the sun takes place at the same time as the shutting off of the light.
2. Radiant heat may pass through a medium without heating it. For example, the air inside a greenhouse may be much warmer than the glass through which the sun's rays pass.
3. Although conducted or convected heat may travel in roundabout routes, radiant heat always travels in a straight line. For example, radiation can be cut off with a screen placed between the source of heat and the body to be protected.

Absorption

The sun, a fire, and an electric light bulb all radiate energy, but a body need not glow to give off heat. A kettle of hot water or a hot soldering iron radiates heat. If the surface is polished or light in color, less heat is radiated. Bodies which do not reflect are good radiators and good absorbers, and bodies that reflect are poor radiators and poor absorbers. This is the reason white clothing is worn in the summer. A practical example of the control of heat is the Thermos bottle. The flask itself is made of two walls of "silvered" glass with a vacuum between them. The vacuum prevents the loss of heat by conduction and convection, and the "silver" coating prevents the loss of heat by radiation.

The silver-colored bronze paint on the "radiators" in heating systems is used only for decoration and decreases the efficiency of heat transfer. The most effective color for heat transfer is dull black; dull black is the ideal absorber and also the best radiator.

MEASUREMENT OF HEAT

A unit of heat must be defined as the heat necessary to produce some agreed on standard of change. There are three such units in common use as follows:

1. One British thermal unit (Btu) is the quantity of heat necessary to raise the temperature of 1 pound of water 1°F.
2. One gram-calorie (small calorie) is the quantity of heat necessary to raise 1 gram of water 1°C.
3. One kilogram-calorie (large calorie) is the quantity of heat necessary to raise 1 kilogram of water 1°C. (One kilogram-calorie equals 1,000 gram-calories.) The gram-calorie or small calorie is much more widely used than the kilogram-calorie or large calorie.

The large calorie is used in relation to food energy and for measuring comparatively large amounts of heat. Throughout this discussion, unless otherwise stated, the term calorie means gram-calorie. For purposes of conversion, one Btu equals 252 gram-calories or 0.252 kilogram-calorie.

The terms quantity of heat and temperature are commonly misused. The distinction between them should be understood clearly. For example, suppose that two identical pans, containing different amounts of water of the same temperature, are placed over identical gas burner flames for the same length of time. At the end of that time, the smaller amount of water will have reached a higher temperature. Equal amounts of heat have been supplied, but the increase in temperatures is not equal. As another example, suppose that the water in both pans is at the same temperature, say 80°F, and both are to be heated to the boiling point. It is obvious that more heat must be supplied to the larger amount of water. The temperature rise is the same for both pans, but the quantities of heat necessary are different.

Mechanical Equivalent

Mechanical energy is usually expressed in ergs, joules, or foot-pounds. Energy in the form of heat is expressed in calories or in Btu's. In a precise experiment in which electric energy is converted into heat in a resistance wire immersed in water, the results show that 4.186 joules equals 1 gram-calorie, or that 778 foot-pounds equals 1 Btu. The following equation is used when converting from the English system to the metric system:

$$1 \text{ Btu} = 252 \text{ calories}$$

Specific Heat

One important way in which substances differ from one another is that they require different quantities of heat to produce the same temperature change in a given mass of substance. The specific heat capacity of a substance is the quantity of heat needed, per unit mass, to increase the temperature 1°C. The specific heat of a substance is the ratio of its specific heat capacity to the specific heat capacity of water. Specific heat is expressed as a number which, because it is a ratio, has no units and applies to both the English and the metric systems.

Water has a high specific heat capacity. Large bodies of water on the earth keep the air and the surface of the earth at a fairly constant temperature. A great quantity of heat is required to change the temperature of a large lake or river. Therefore, when the temperature of the air falls below that of such bodies of water, they give off large quantities of heat to the air. This process keeps the atmospheric temperature at the surface of the earth from changing very rapidly.

TEMPERATURE

If an object is hot to the touch, it is said to have a "high" temperature; if it is cold to the touch, it has a "low" temperature. In other words, temperature is used as a measure of the hotness or coldness of an object being described. However, hotness and coldness are only relative. For example, on a cold day, metals seem colder to the touch than nonmetals because they conduct heat away from the body more rapidly. Also, upon leaving a warm room the outside air seems cooler than it really is. Going from the outside cold into a warm room, the room seems warmer than it really is. In other words, the temperature a person feels depends upon the state of his body.

Thermometers

The measurement of temperature is known as THERMOMETRY. Many modern thermometers use liquids in sealed containers. Water was the first liquid used; but because it freezes at 0°C, it could not measure temperatures below that point. After much experimentation, scientists decided that the best liquids to use in the construction of thermometers are alcohol and mercury because of the low freezing points of these liquids.

LIQUID THERMOMETERS.—The construction of the common laboratory thermometer gives some idea as to the meaning of a change of 1° in temperature. A bulb is blown at one end of a piece of glass tubing of small bore. The tube and bulb are then filled with the liquid to be used. The temperature of both the liquid and the tube during this process are kept at a point higher than the thermometer will reach in normal usage. The glass tube is then sealed and the thermometer is allowed to cool. During the cooling process, the liquid falls away from the top of the tube and creates a vacuum within the thermometer.

For marking, the thermometer is placed in melting ice. The height of the liquid column is marked as the 0°C point. Next, the thermometer is placed in steam at a pressure of 76 centimeters of mercury, and a mark is made at that point to which the liquid inside rises; that is, the boiling point or the 100°C mark. The space between these two marks is then divided into 100 equal parts. These spacings are known as DEGREES. It is this type of thermometer that is used almost exclusively in laboratory work and in testing electrical equipment. It is known as the Celsius thermometer.

NOTE: This type of temperature scale was formerly known as the centigrade scale, but was renamed the Celsius scale in recognition of Anders Celsius, the Swedish astronomer, who devised the scale.

In English-speaking countries, the FAHRENHEIT thermometer is commonly used for other than physical or chemical laboratory purposes. The freezing point is marked 32° and the boiling point is marked 212°. The space between these marks is divided into 180 equal parts. These divisions are degrees Fahrenheit, named after the scientist who made the first thermometer of this type. In the U.S., weather reports and room temperatures are given in degrees Fahrenheit.

TEMPERATURE CONVERSION.—There are two systems of temperature measurement; it is frequently necessary to convert from one to the other. The range on the Celsius thermometer from the freezing point to the boiling point is 100°C, and the same range on the Fahrenheit thermometer is 180° F. Thus, over the same temperature range, the liquid moves 180 divisions on the Fahrenheit scale for every 100 divisions on the Celsius scale. A change of 5° on the Celsius scale, therefore, is equal to a change of 9° on the Fahrenheit scale. (The ratio 100/180 reduces to 5/9.) Because zero on the Celsius scale corresponds to 32° on the Fahrenheit scale, a difference in reference points exists between the two scales. (See fig. 3-13.)

To convert from the Fahrenheit scale to the Celsius scale, subtract the 32° difference and multiply the result by 5/9. As an example, convert 68° Fahrenheit to Celsius—

$$\frac{5}{9}(68 - 32)$$

$$\frac{5}{9} \times 36 = 20\,^{\circ}\mathrm{C}$$

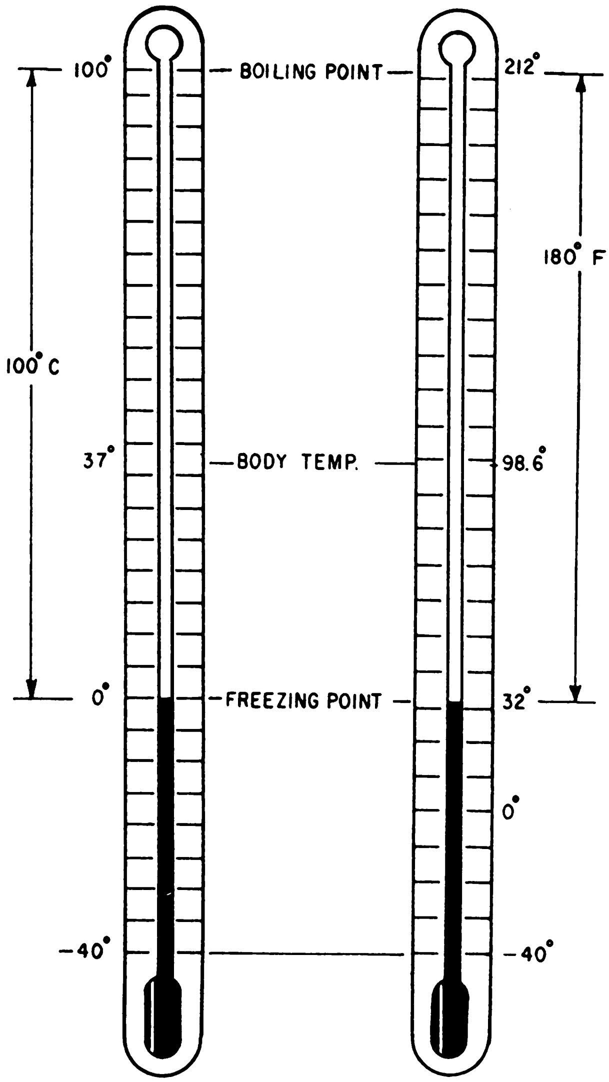

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Figure 3-13.—Celsius (centigrade) and Fahrenheit thermometer.

To convert Celsius to Fahrenheit, the reverse procedure is necessary. First multiply the reading on the Celsius thermometer by 9/5 and then add 32 to the result—

$$\frac{9}{5}(20) + 32$$

$$36 + 32 = 68\,^{\circ}\mathrm{F}$$

One way to remember when to use 9/5 and when to use 5/9 is to keep in mind that the

Fahrenheit scale has more divisions than the Celsius scale. In going from Celsius to Fahrenheit, multiply by the ratio that is larger; in going from Fahrenheit to Celsius, use the smaller ratio.

Another method of temperature conversion which uses these same ratios is based on the fact that the Fahrenheit and Celsius scales both register the same temperature at -40°; that is, -40°F equals -40°C. This method of conversion, sometimes called the "40 rule," proceeds as follows:

1. Add 40 to the temperature which is to be converted. Do this whether the given temperature is Fahrenheit or Celsius.
2. Multiply by 9/5 when changing Celsius to Fahrenheit; by 5/9 when changing Fahrenheit to Celsius.
3. Subtract 40 from the result of stop 2. This is the answer.

As an example to show how the 40 rule is used, convert 100°C to the equivalent Fahrenheit temperature:

$$100 + 40 = 140$$

$$140 \times 9/5 = 252$$

$$252 - 40 = 212$$

Therefore, 100°C = 212°F. Remember that the multiplying ratio for converting F to C is 5/9, rather than 9/5. Also remember to always ADD 40 first, then multiply, then SUBTRACT 40, regardless of the direction of the conversion.

Thermometers are provided on many different types of support equipment. For example, thermometers are provided to check engine operating temperatures. They are also used in some hydraulic systems to check the operating temperature of the hydraulic fluid.

SOLID THERMOMETERS.—Because the range of all liquid thermometers is extremely limited, other methods of thermometry are necessary. Most liquids freeze at temperatures between 0° and -200° Celsius. At the upper end of the temperature range where high heat levels are encountered, the use of liquid thermometers is limited by the high vapor pressures of those liquids. Among the most widely used types of thermometers other than the standard liquid thermometers are the resistance thermometer and the thermocouple.

The RESISTANCE THERMOMETER makes use of the fact that the resistance of metals changes as the temperature changes. (Refer to Basic Electricity, NavPers 10086 (Series).) This type thermometer is usually constructed of platinum wire wound on a mica form and enclosed in a thin-walled silver tube. It is extremely accurate from the lowest temperature to the melting point of the unit. Most of the thermometers used on support equipment to check engine operating temperatures and hydraulic fluid temperatures are of the resistance type.

The THERMOCOUPLE shown in figure 3-14 is essentially an electric circuit. Its operation is based on the principle that when two unlike metals are joined and the junction is at a different temperature than the remainder of the circuit, an electromotive force is produced. This electromotive force can be measured with great accuracy by a galvanometer. Thermocouples can be located wherever measurement of the temperature is important and wires run to a galvanometer located at any convenient point. By means of a rotary selector switch, one galvanometer can read the temperatures at any of a number of widely separated points. The thermocouple is used on gas turbine engines for checking exhaust temperatures.

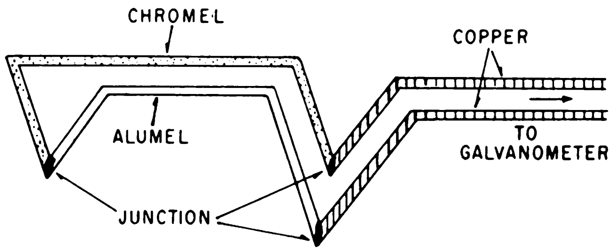

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Figure 3-14.—Thermocouple.

Thermal Expansion

Nearly all substances expand or increase in size when their temperature increases. Railroad tracks are laid with small gaps between the sections to prevent buckling when the temperature increases in summer. Concrete pavement has strips of soft material inserted at intervals to prevent buckling when the sun heats the roadway. A steel building or bridge is put together with red-hot rivets so that when the

rivets cool they will shrink and the separate pieces will be pulled together very tightly.

As a substance is expanded by heat, the weight per unit volume decreases. This is because the weight of the substance remains the same while the volume is increased by the application of heat. Thus the density decreases with an increase in temperature.

Experiments show that for a given change in temperature, the change in length or volume is different for each substance. For example, a given change in temperature causes a piece of copper to expand nearly twice as much as a piece of glass of the same size and shape.

Thermal expansion and contraction have a great effect on metals during the welding process. Some of these effects and the methods used to compensate for them are discussed in chapter 7.

The amount that a unit length of any substance expands for a 1° rise in temperature is known as the coefficient of linear expansion for that substance.

COEFFICIENTS OF EXPANSION.—To estimate the expansion of any object, such as a steel rail, it is necessary to know three things about it—its length, the rise in temperature to which it is subjected, and its rate or coefficient of expansion. The amount of expansion is expressed by the following equation:

expansion = coefficient x length

x rise in temperature

or

$$e = kl\,(t_2 - t_1)$$

In this equation, the letter k represents the coefficient of expansion for the particular substance. In some instances, the Greek letter α (alpha) is used to indicate the coefficient of linear expansion.

PROBLEM: If a steel rod measures exactly 9 feet at 21°C, what is its length at 55°C? (The coefficient of linear expansion for steel is 10×10^{-6}.) If the equation $e = kl\,(t_2 - t_1)$ is used, then

$$e = (10 \times 10^{-6}) \times 9 \times (55 - 21)$$

$$e = 0.000010 \times 9 \times 34$$

$$e = 0.00306$$

This amount, when added to the original length of the rod, makes the rod 9.00306 feet long. (Since the temperature has increased, the rod is longer by the amount of e. If the temperature had been lowered, the rod would have become shorter by a corresponding amount.)

The increase in the length of the rod is relatively small; but if the rod were placed where it could not expand freely, there would be a tremendous force exerted due to thermal expansion. Thus, thermal expansion must be taken into consideration when designing ships, buildings, and all forms of machinery.

Since the coefficient of linear expansion is defined as the change in unit length, its value does not depend upon any particular length unit. Its value, however, does depend upon the size of the degree used to measure the temperature change. Table 3-2 gives the value of the coefficient of linear expansion of several substances per Celsius degree. The coefficient of expansion per Fahrenheit degree will be just 5/9 as much.

Table 3-2.—Expansion coefficients (per Celsius degree).

Substance	Coefficient of linear expansion
Aluminum	24×10^{-6}
Brass	20×10^{-6}
Copper	14×10^{-6}
Glass	4 to 9×10^{-6}
Covar	4 to 9×10^{-6}
Steel	10×10^{-6}
Quartz	0.4×10^{-6}
Zinc	26×10^{-6}

A practical application for the difference in the coefficients of linear expansion is the thermostat. This instrument comprises two strips of dissimilar metal fastened together. When the temperature changes, a bending takes place due to the unequal expansion of the metals (fig. 3-15.) Thermostats are used in overload relays for motors, in temperature-sensitive switches, and in electric ovens. (See fig. 3-16.)

The coefficient of surface or area expansion is approximately twice the coefficient of linear

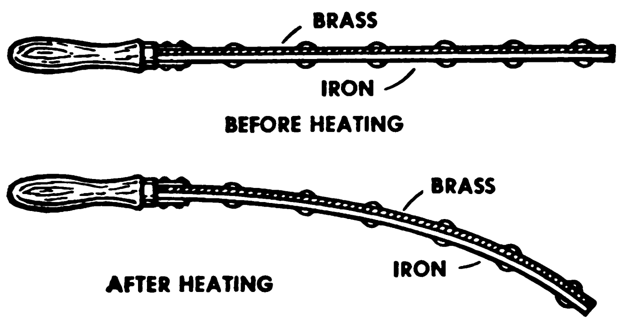

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Figure 3-15.—Compound bar.

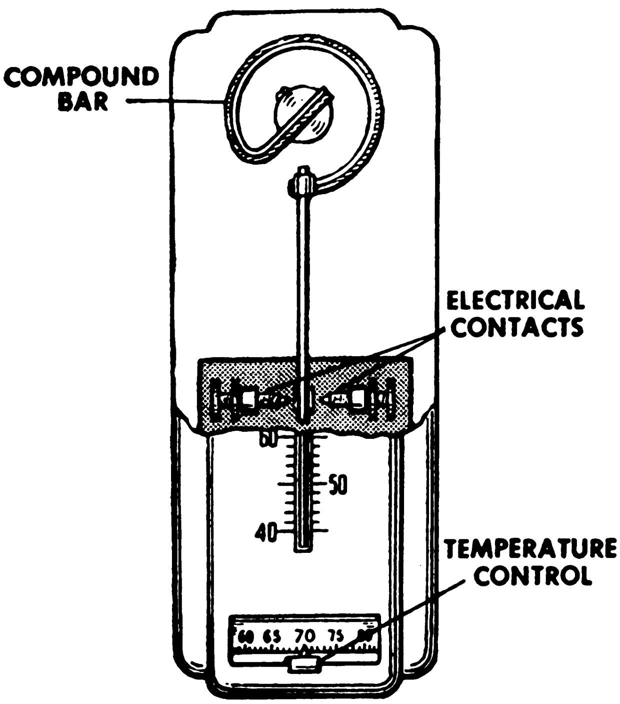

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Figure 3-16.—Thermostat.

expansion. The coefficient of volume expansion is approximately three times the coefficient of linear expansion. It is interesting to note that in a plate containing a hole, the area of the hole expands at the same rate as the surrounding material. In the case of a volume enclosed by a thin solid wall, the volume expands at the same rate as would a solid body of the material of which the walls are made.

CHANGE OF STATE

A thermometer placed in melting snow behaves in a strange manner. The temperature of the snow rises slowly until it reaches 0°C. Provided that the mixture is stirred constantly, it remains at that point until all the snow has changed to water; when all the snow has melted, the temperature again begins to rise. A definite amount of heat is required to change the snow to water at the same temperature. This heat is required to change the water from crystal form to liquid form.

Heat of Fusion

Eighty gram-calories of heat are required to change 1 gram of ice at 0°C to water at 0°C. In English units, the heat required to change 1 pound of ice at 32°F to water at 32°F is 144 Btu's. These values are called the HEAT OF FUSION of water. The heat used while the ice is melting represents the work done to produce the change of state. Since 80 calories are required to change a gram of ice to water at 0°C, when a gram of water is frozen it gives up 80 calories.

Many substances behave very much like water. At a given pressure, they have a definite heat of fusion and an exact melting point. There are many materials, however, which do not change from a liquid to a solid state at one temperature. Molasses, for example, becomes thicker and thicker as the temperature decreases; but there is no exact temperature at which the change of state occurs. Wax, celluloid, clay, and glass are other substances which do not change from a liquid to a solid state at any particular temperature. In fact, measurements of the glass thickness at the bottom of windows in ancient cathedrals tend to indicate that the glass is still flowing at an extremely slow rate. Most types of solder used in maintenance also tend to become mushy before melting.

Heat of Vaporization

Damp clothing dries rapidly under a hot flatiron but not under a cold one. A pool of water evaporates more rapidly in the sun than in the

shade. Thus, it may be concluded that heat has something to do with evaporation. The process of changing a liquid to a vapor is similar to that which occurs when a solid melts.

If a given quantity of water is heated until it evaporates—that is, changes to a gas (vapor)—a much greater amount of heat is used than that which is necessary to raise the same amount of water to the boiling point. For example, several hundred calories are required to change 1 gram of water to vapor at a given temperature. It takes 972 Btu's to change 1 pound of water at 212°F to water vapor (steam) at 212°F. The amount of heat necessary for this change is called the HEAT OF VAPORIZATION of water. Over five times as much heat is required to change a given amount of water to vapor than to raise the same amount of water from the freezing to the boiling point.

BOILING.—When water is heated, some vapor forms before the boiling point is reached. The change from water to vapor occurs as follows: As the water molecules take up more and more energy from the heating source, their kinetic energy increases. The motion resulting from the high kinetic energy of the water molecules causes a pressure which is called the vapor pressure. As the velocity of the molecules increases, the vapor pressure increases. At sea level, atmospheric pressure is normally 29.92 inches of mercury. The boiling point of a liquid is that temperature at which the vapor pressure equals the external or atmospheric pressure. At normal atmospheric pressure at sea level, the boiling point of water is 100°C or 212°F.

While the water is below the boiling point, a number of molecules acquire enough kinetic energy to break away from the liquid state into a vapor. For this reason some evaporation slowly takes place below the boiling point. At the boiling point or above, large numbers of molecules have enough energy to change from liquid to vapor and the evaporation takes place much more rapidly.

If the molecules of water are changing to water vapor in an open space, the air currents carry them away quickly. In a closed container, they rapidly become crowded and some of them bounce back into the liquid as a result of collisions. When as many molecules are returning to the liquid state as are leaving it, the vapor is said to be saturated. Experiments have shown that saturated vapor in a closed container exerts a pressure and has a given density at every temperature.

LIGHT

The exact nature of light is not fully understood, although men have been studying the subject for many centuries. Some experiments seem to show that light is composed of tiny particles, and some indicate that it is made up of waves.

First one theory and then the other attracted the approval and acceptance of the physicists. Today there are scientific phonomena which can be explained only by the wave theory and another large group of occurrences which can be made clear by the particle or corpuscular theory. Physicists, constantly searching for some new discovery which would bring these contradictory theories into agreement, gradually have come to accept a theory concerning light which is a combination of these two views.

According to the view now generally accepted, light is a form of electromagnetic radiation; that is, light and similar forms of radiation are made up of moving electric and magnetic forces.

CHARACTERISTICS

When light waves, which travel in straight lines, encounter any substance, they are transmitted, reflected, or absorbed. (See fig. 3-17.) Those substances which permit clear vision through them, and which transmit almost all the light falling upon them, are said to be transparent. Those substances which allow the passage of part of the light, but appear clouded and impair vision substantially, are called translucent. Those substances which transmit no light are called opaque.

Objects which are not light sources are visible only because they reflect all or part of the light reaching them from some luminous source. If light is neither transmitted nor reflected, it is absorbed or taken up by the medium. When light strikes a substance, some absorption and reflection always take place. No substance completely transmits, reflects, or absorbs all the light which reaches its surface. Figure 3-17 shows how glass transmits, absorbs, and reflects light.

Reflection

Light waves obey the law of reflection in the same manner as other types of waves. Optical devices incorporated specifically for the

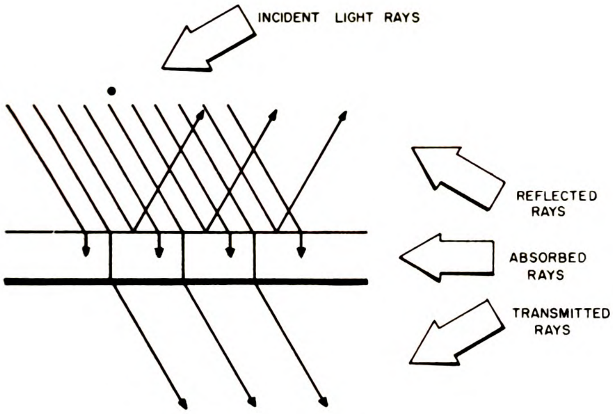

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Figure 3-17.—Light rays reflected, absorbed, and transmitted.

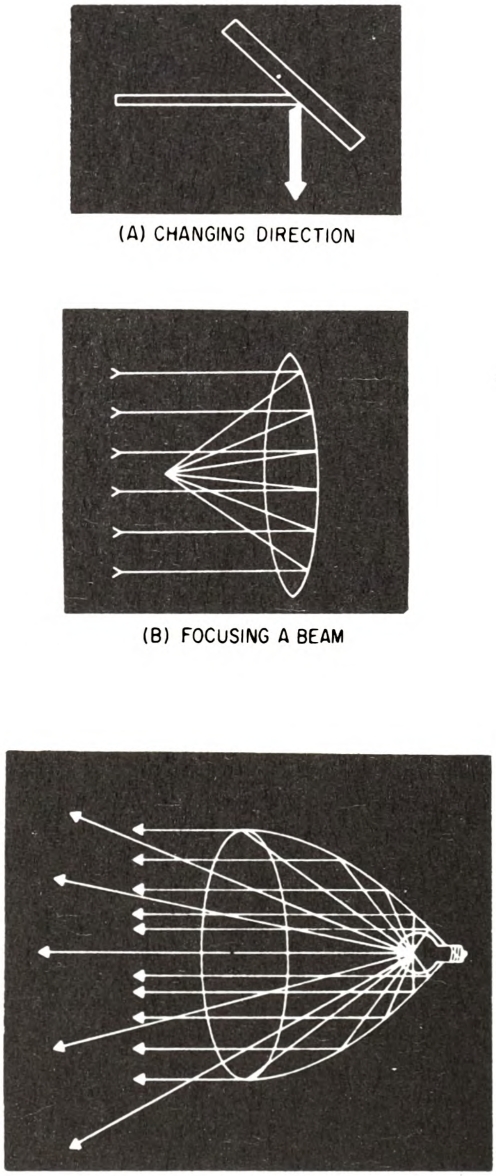

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Figure 3-18.—Reflectors of light. (A) Changing direction; (B) focusing a beam; (C) illuminating an area.

purpose of reflecting light are generally classed as mirrors. They may be of a polished opaque surface, or they may be a specially coated glass. In the case of the glass mirror, there is some refraction as well as reflection; however, if the glass is of good quality and not excessively thick, the refraction will cause no trouble. The following discussion is based on the polished surface type mirror.

Several classes of mirrors are illustrated in figure 3-18. All the devices work on the basis of the previously discussed law of reflection, and the applications are only briefly summarized here. Basically, the reflector is used to change the direction of a light beam (A), to focus a beam of light (B), or to intensify the illumination of an area (C).

In figure 3-18(A), the angle of the reflected light may be changed to a greater or lesser degree by merely changing the angle at which the incident light impinges upon the mirror. In figure 3-18(B), the focusing action of a concave mirror is indicated. The point of focus may be made any convenient distance from the reflector by proper selection of the arc of curvature of the mirror—the sharper the curvature, the shorter the focal length. In figure 3-18(C), the principle of intensification of illumination for a specific area is illustrated. The flashlight is an example of this application. In the system shown, note that the light source (bulb) is located approximately at the principal focus point, and that all rays reflected from the surface are parallel. Also note that the reflector alone does not concentrate all the rays—some are transmitted without being reflected and are not included in the principal beam.

Refraction

As light passes through a transparent substance, it travels in a straight line. However, as it passes into or out of that substance, it is refracted in the same manner as other waves which were discussed earlier. Refraction of light waves results from the fact that light travels at slightly different velocity in different transparent mediums. In order to simplify the problem of understanding the action of light reflection and to make it possible to predict the outcome of specific applications, many transparent substances have been tested for refractive effectiveness. The ratio of the speed of light in air to its speed in each transparent substance is called the "index of refraction" for that substance. For example, light travels about one and one-half times as fast in air as it does in glass, so the index of refraction of glass is about 1.5. When using the law of refraction in connection with light, a "denser" medium refers to a medium with a higher index of refraction.

Refraction through a piece of plate glass is shown in figure 3-19. The ray of light strikes the glass plate at an oblique angle. If it were to continue in a straight line, it would emerge from the plate at point A; but in accordance with the law of refraction, it is bent toward the normal and emerges from the glass at point B. Upon entering the air, the ray does not continue on its path but is bent away from the normal and along the path BC in the air. If the two surfaces of the glass are parallel, the ray leaving the glass is parallel to the ray entering the glass. The displacement depends upon the thickness of the glass plate, the angle of entry into it, and the index of refraction for the glass.

All rays striking the glass at any angle other than perpendicular are refracted in the same manner. In the case of a perpendicular ray, no refraction takes place, and the ray continues through the glass and into the air in a straight line.

PRISMS.—When a ray of light passes through a flat sheet of glass, it emerges parallel to the incident ray. This holds true only when the two surfaces of the glass are parallel. When the two surfaces are not parallel, as in a prism, the ray is refracted differently at each surface of the glass and does not emerge parallel to the incident ray.

Figure 3-20(A) shows that both refractions are in the same direction, and that the ray coming out of the prism is not parallel to the ray going into it. The law of refraction explains what has happened. When the ray entered the prism, it was bent toward the normal; and when it emerged, it was bent away from the normal. Notice that the deviation is the result of the two normals not being parallel.

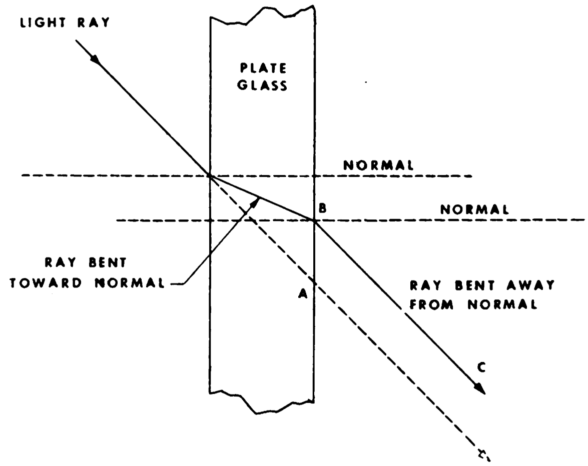

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Figure 3-19.—Refraction through a piece of plate glass.

If two triangular prisms are placed base to base, as in figure 3-20(B), parallel incident rays passing through them are refracted and caused to intersect. The rays passing through different parts of the prisms, however, do not intersect at the same point. In the case of two prisms there are only four refracting surfaces. The light rays from different points on the same plane are not refracted to a point on the same plane behind the prism. They emerge from the prisms and intersect at different points along an extended common baseline as illustrated by points A, B, and C of figure 3-20(B).

Parallel incident light rays falling upon two prisms that have been joined apex to apex (fig. 3-20(C)), are spread apart. The upper prism refracts light rays toward its base; the lower prism refracts light rays downward toward its base, causing the two sets of rays to diverge.

POSITIVE LENSES.—A positive (convergent) lens acts like two prisms base to base with their surfaces rounded off into a curve. Rays that strike the upper half of the lens bend downward, and rays that strike the lower half bend upward. A good lens causes all wavelengths

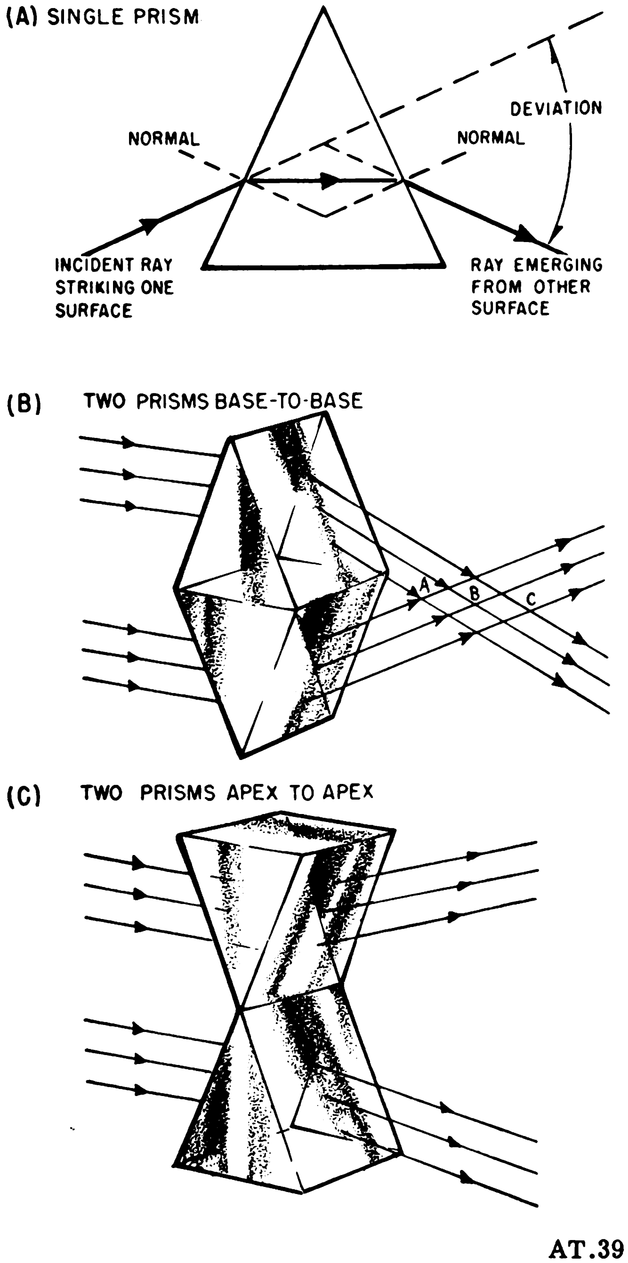

Figure 3-20.—Passage of light through a prism. (A) Single prism; (B) two prisms, base to base; (C) two prisms, apex to apex.

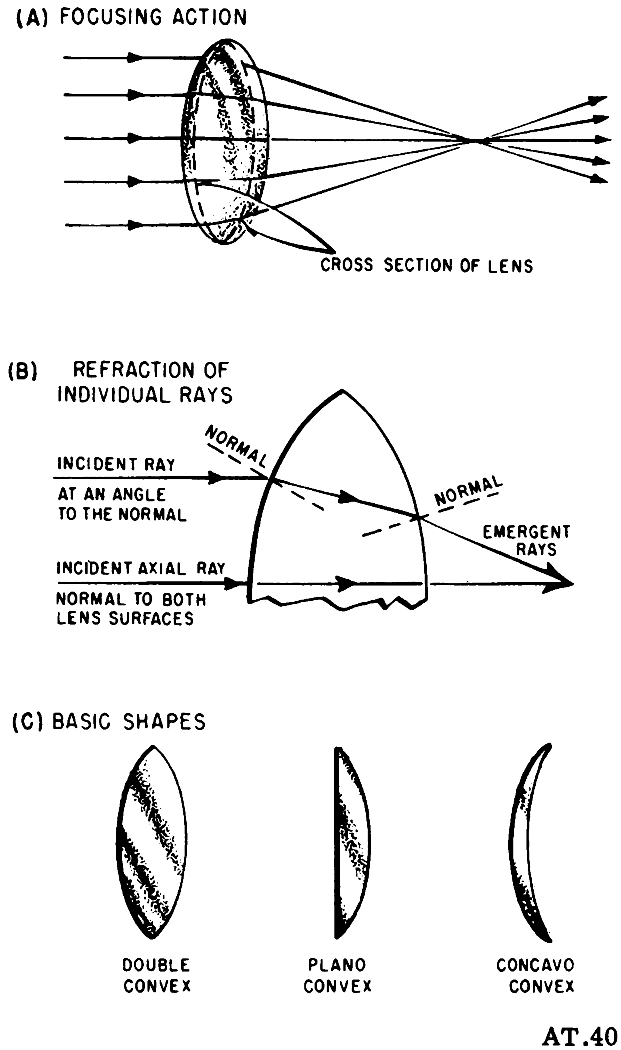

Figure 3-21.—Positive lenses.

within each ray to cross at the same point behind the lens as shown in figure 3-21(A).

When the incident ray of light enters the denser medium (the lens), it bends toward the normal. When it passes through into the less dense medium (the air), it bends away from the normal. Figure 3-21(B) illustrates the refraction of only one ray of light, but all rays passing through a positive lens are affected in the same way. All incident light rays either parallel or slightly diverging will converge to a point after passing through a positive lens.

The only ray of light that can pass through a lens without bending is the ray which strikes the first surface of the lens at a right angle, perpendicular or normal to the surface. It passes through that surface without bending and strikes the second surface at the same angle. It leaves the lens without bending. This ray is shown in figure 3-21(B).

Positive lens and convergent lens are synonymous terms, since either of them may be used to describe the action of a lens which

focuses (brings to a point of convergence) all light rays passing through it. All simple positive lenses are easy to identify since they are thicker in the center than at the edges. The three most common types of simple positive lenses are shown in figure 3-21(C).

NEGATIVE LENSES.—Figure 3-22 illustrates the refraction of light rays by two prisms apex to apex. If the prism surfaces are rounded the result is a negative (divergent) lens. A negative lens is called a divergent lens since it does not focus the rays of light passing through it. Light rays passing through a negative lens diverge or spread apart as shown in figure 3-22(A).

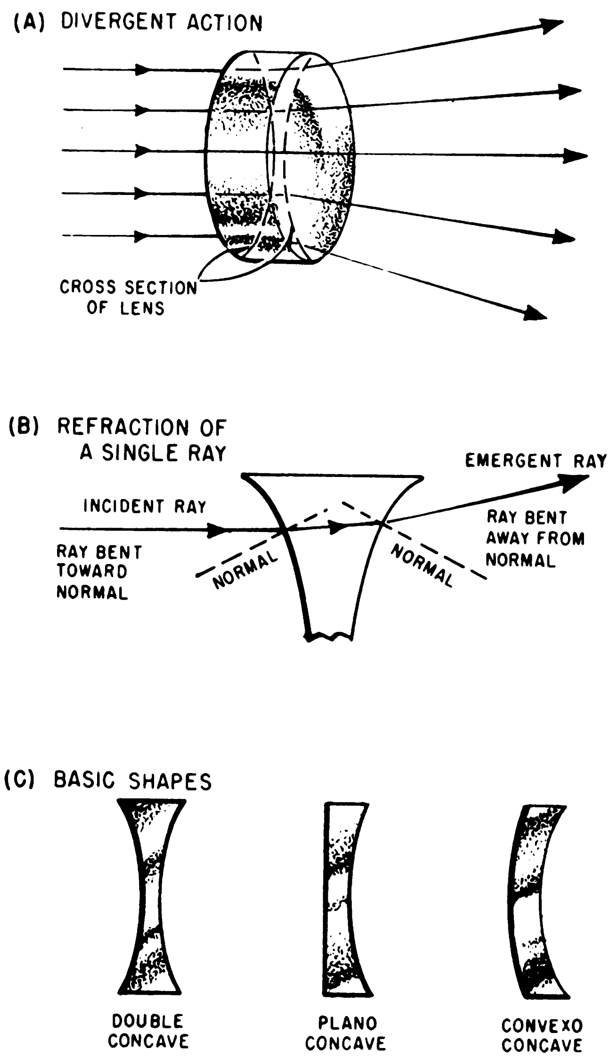

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Figure 3-22.—Negative lenses.

Figure 3-22(B) applies the law of refraction to one ray of light passing through a negative lens. Just as in a positive lens, a ray of light passing through the center of a negative lens is not affected by refraction and passes through without bending.

Three simple negative lenses are shown in figure 3-22(C). They are often referred to as concave lenses and are readily identified by their concave surfaces. The simple negative lenses are thicker at the edges than at the center. They are generally used in conjunction with simple positive lenses where their primary use is to assist in the formation of a sharper image by helping to eliminate or subdue various defects present in an uncorrected simple positive lens.

FREQUENCIES AND COLOR

The electromagnetic waves which produce the sensation of light are all very high in frequency, which means that they have very short wavelengths. These wavelengths are measured in millimicrons (millionths of millimeters, or 10^{-9} meters). Figure 3-23 indicates that light with a wavelength of 700 millimicrons is red, and that a light with a wavelength of 500 millimicrons is blue-green. This drawing is subject to erroneous interpretation. In actual fact, the color of light is dependent on its frequency, not its wavelength.

When the wavelength of 700 millimicrons is measured in air, it produces a color known as red, but the same wave measured in another medium has a wavelength other than 700 millimicrons. When red light which has been traveling in air enters glass, it loses speed and its wavelength becomes shorter or compressed, but it continues to be red. This illustrates that the color of light is dependent upon frequency and not on wavelength. The color scale in figure 3-23 is based on the wavelengths in air.

All color-component wavelengths of the visible spectrum are present in equal amounts in white light. Variations in composition of the component wavelengths result in other characteristic colors.

When a beam of white light is passed through a prism, as shown in figure 3-23, it is refracted and dispersed into its component wavelengths. Each of these wavelengths reacts differently on the eye which then sees the various colors that compose the visible spectrum. The visible spectrum is recorded as a mixture of red,

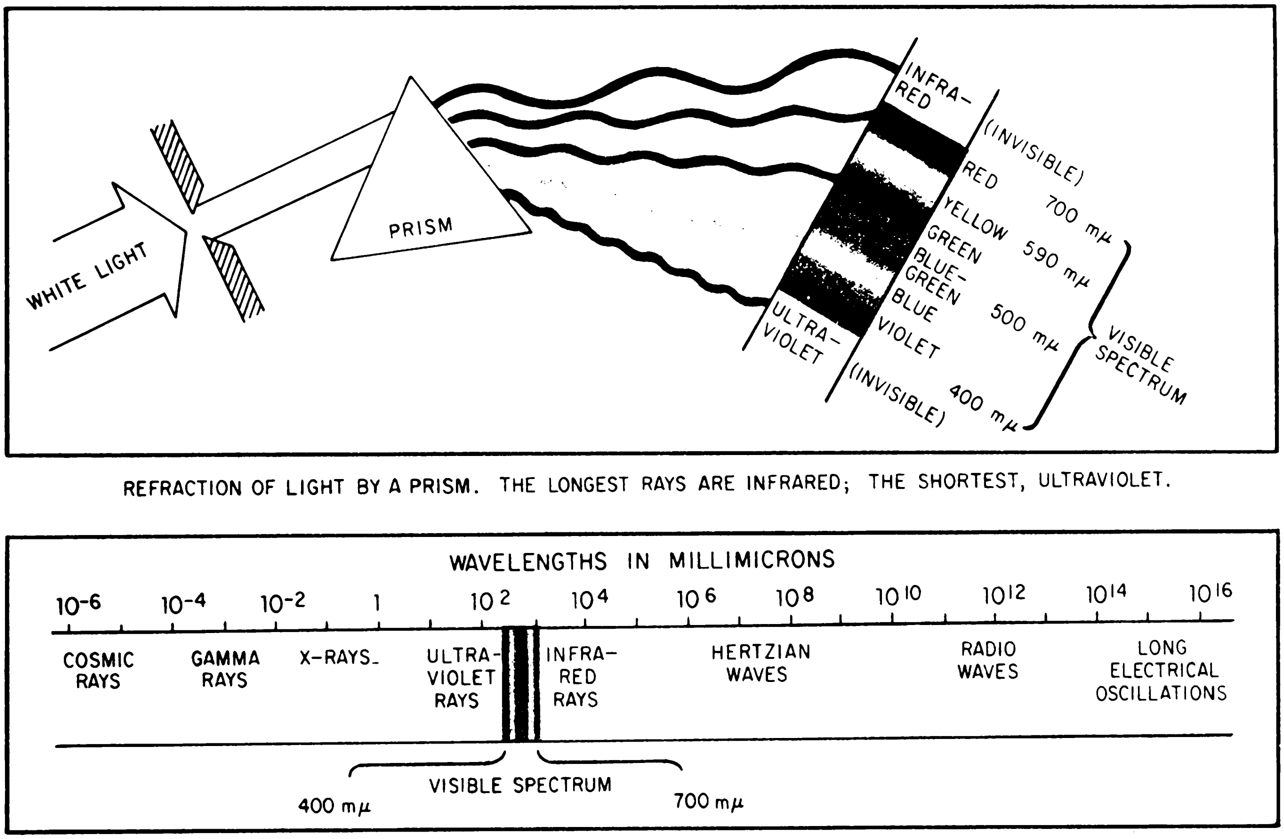

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Figure 3-23.—Electromagnetic wavelengths and the refraction of light.

orange, yellow, green, blue, indigo, and violet. It can be readily demonstrated that white light results when the PRIMARIES (red, green, and blue) are mixed together in overlapping beams of light. (NOTE: These are not the primaries used in mixing pigments.) Furthermore, the COMPLEMENTARY or secondary colors (magenta, yellow, and cyan) may be shown with equal ease by mixing any two of the primary colors in overlapping beams of light. Thus, red and green light mixed in equal intensities will make yellow light; green and blue will produce blue-green light which is termed cyan; and blue and red light correctly mixed will render magenta (a purplish red).

It should be noted that a few modern texts vary the treatment of the color scale slightly from the seven spectral colors. This is due partly to developments in the mixing values of pigments (paints). This difference in approach is based on a theory that the retina of the eye is equipped with three varying groups of nerves, sensitive roughly to red, green, and blue-violet light.

SOUND

BASIC CONSIDERATIONS

The term sound as generally used refers to hearing; but when used in physics, the term has to do with a particular type of wave motion and with the generation, transmission, detection, characteristics, and effects of those waves.

One example of the generation and transmission of sound waves is the tuning fork discussed earlier in this chapter. Any object which moves rapidly to and fro, or which vibrates rapidly in such a manner as to disturb the surrounding medium, may become a sound source. Sound requires three components—a source, a medium for transmission, and a detector. As

widely different as sound sources may be, the waves they produce have certain basic characteristics.

Wave Motion

Sound waves are longitudinal type waves which rely on a physical medium for transmission. Since the waves are transmitted by the compression and rarefaction of particles of matter in the medium, they cannot be transmitted through a vacuum. Sound waves are similar to waves of other types in that they can be reflected, absorbed, or refracted according to the laws previously discussed.

The major differences between the waves of sound and the waves of heat and light are the frequencies, the nature of the wave, and the velocities of wave travel.

Frequencies

Sound waves vary in length; a long wavelength is heard as a low sound, while a short wavelength is heard as a high sound. If the sound is below 15 hertz or above 20,000 hertz, it normally cannot be heard by the human ear. The frequency range over which sound can be heard is called the audible range, and the sounds heard are known as sonics. Sounds below 15 hertz are subsonics; those above 20,000 hertz are ultrasonics.

Conduction Media and Velocity of Transmission

In any uniform medium under given physical conditions, sound travels at a definite speed. In some substances, the velocity of sound is higher than in others. Even in the same medium under different conditions of temperature and pressure, the velocity of sound varies. Density and elasticity of a medium are basic physical properties which govern the velocity of sound.

At a given temperature and pressure, all sound waves travel at the same speed in air, regardless of frequency or wavelength. The speed of sound, however, does increase with temperature at the rate of 2.0 feet per second (fps) per degree Celsius. For practical purposes, the speed of sound in air may be considered 1,100 fps. Refer to table 3-3 for speed of sound in various media at different temperatures.

Table 3-3.—Comparison of velocity of sound in various media.

Medium	Temperature (°F)	Velocity (ft/sec)
Air	32	1,087
Air	68	1,127
Fresh water	32	4,629
Fresh water	68	4,805
Salt water	32	4,800
Salt water	68	4,953
Steel	32	16,410
Steel	68	16,850

As previously stated, a sound wave is a compressional wave transmitted through an elastic medium. Sound travels faster through water (4,800 fps) than air (1,087 fps) because the elasticity of water is greater than that of air.

For a fixed temperature, the velocity of sound is constant for any medium and is independent of the period, frequency, or amplitude of the disturbance. Thus, the velocity of sound in air at 0°C (32°F) is 1,087 fps and increases by 2 fps for each degree Celsius rise in temperature (1.1 fps for each degree Fahrenheit).

The velocity of sound also varies with a change in altitude. With an increase in altitude, the atmospheric pressure is reduced, and the medium is less dense. Sound waves travel slower in a less dense medium. Therefore, it may be considered that the velocity of sound varies inversely with the altitude.

Characteristics

Numerous terms are used to convey impressions of sounds, including whistle, scream, rumble, and hum. Most of these are classified as noises in contrast to musical tones. The distinction is based on the regularity of the vibrations, the degree of damping, and the ability of the ear to recognize components having a musical sequence.

The ear can distinguish tones that are different in pitch, intensity, or quality. Each of these characteristics is associated with one of the properties of the vibrating source or of the waves that the source produces. Thus, pitch is determined by the number of vibrations per second, intensity by the amplitude of the wave motion, and quality by the number of overtones (harmonics) which the wave contains. A sound wave can best be described by its frequency rather than by its velocity or wavelength, as both the velocity and the wavelength change when the temperature of the air changes.

PITCH.—The term pitch is used to describe the frequency of a sound. The outstanding recognizable difference between the tones produced by two different keys on a piano is a difference in pitch. The pitch of a tone is proportional to the number of compressions and rarefactions received per second, which in turn is determined by the vibration frequency of the sounding source.

Pitch is usually measured by comparison with a standard. The standard tone may be produced by a tuning fork of known frequency or by a siren whose frequency is computed for a particular speed of rotation. By regulating the speed, the pitch of the siren is made equal to that of the tone being measured. The ear can determine this equality directly if the two sources are sounded alternately, or by the elimination of beats by regulating the speed of the siren if the two sources are sounded together.

INTENSITY.—When a bell rings, the sound waves spread out in all directions and the sound is heard in all directions. When a bell is struck lightly, the vibrations are of small amplitude and the sound is weak. A stronger blow produces vibrations of greater amplitude in the bell, and the sound is louder. It is evident that the amplitude of the air vibrations is greater when the amplitude of the vibrations of the source is increased. Hence the loudness of the sound depends on the amplitude of the vibrations of the sound waves. As the distance from the source increases, the energy in each wave spreads out, and the sound becomes weaker.

The intensity of sound is the energy per unit area per second. In a sound wave of simple harmonic motion, the energy is half kinetic and half potential; half is due to the speed of the particles, and half is due to the compression and rarefaction of the medium. These two energies are 90° out of phase at any instant—that is, when the speed of particle motion is at a maximum, the pressure is normal; and when the pressure is at a maximum or a minimum, the speed of the particles is zero.

The loudness of sound depends upon both intensity and frequency. The intensity of a sound wave in a given medium is proportional to the following 4 quantities:

1. Square of the frequency of vibration.
2. Square of the amplitude.
3. Density of the medium.
4. Velocity of propagation.

At any distance from a point source of sound, the intensity of the wave varies inversely as the square of the distance from the source.

As a sound wave advances, variations in pressure occur at all points in the transmitting medium. The greater the pressure variations, the more intense the sound wave will be. It can be shown that the intensity is proportional to the square of the pressure variation regardless of the frequency. Thus, by measuring pressure changes, the intensities of sounds having different frequencies can be compared directly.

QUALITY.—Most sounds and musical notes are not pure tones. They are mixtures of tones of different frequencies. The tones produced by most sources can be represented by composite waves in which the sound of lowest pitch, the fundamental tone, is accompanied by several harmonics or overtones having frequencies that are 2, 3, 4 or more times that of the fundamental frequency. The quality of a tone depends on the number of overtones present and on their frequencies and intensities relative to the fundamental tone. It is this characteristic difference in quality that distinguishes tones of like pitch and intensity when sounded on different types of musical instruments (piano, organ, violin, etc.).

ACOUSTICS

Acoustics is the science that deals with effects on sound in a certain area. The performance of an announcing system or sound system when used in a room or enclosed space depends on the acoustical characteristics of the enclosure. Sound originating in an enclosed space is partly reflected and partly absorbed by enclosing surfaces such as the walls, ceiling, and floor of a room. This action introduces echoes and reverberations, which may seriously impair the quality or character of the sound.

Acoustical Disturbances

Light is often thought of first whenever reflection is discussed; however, reflection is equally common in other waves. As an example, echoes are caused by reflection of sound waves.

ECHO.—An ECHO is the repetition of a sound caused by the reflections of sound waves. When a surface of a room is situated so that a reflection from it is outstanding, it appears as a distinct echo, and is heard an appreciable interval later than the direct sound. If the surface is concave, it may have a focusing effect and concentrate the reflected sound energy at one locality. Such a reflection may be several levels higher in intensity than the direct sound, and its arrival at a later time may be particularly disturbing. Some possible remedies for this condition are as follows:

1. Cover the offending surface with absorbing material to reduce the intensity of the reflected sound.
2. Change the contour of the offending surface and thus send the reflected sound in another direction.
3. Locate the loudspeaker in a different position.
4. Vary the amplitude or the pitch of the signal.

REVERBERATION is the persistence of sound due to the multiple reflection of sound waves between several surfaces of an enclosure. It is one of the most common acoustical defects of a large enclosure. Its duration varies directly with the time interval between reflections (the size of the enclosure) and inversely with the absorbing efficiency of the reflecting surfaces. The result is an overlapping of the original sound and its images. If excessive, reverberation causes a general confusion that is detrimental to speech intelligibility. The hangar deck of an aircraft carrier is an example of an extremely reverberant area. The volume is large, and the hard steel interior surfaces offer very little absorption to sound.

If a single loudspeaker is mounted in a large reverberant area, such as a hangar deck, the intelligibility directly in front of the loudspeaker is satisfactory. The intelligibility decreases rapidly with an increase of either the distance from the loudspeaker or the angle between the listener and the loudspeaker's sound axis. In other words, sound from a loudspeaker in a reverberant space is composed of direct sound that reaches the listener directly without any reflection, and indirect sound that has received at least one reflection.

Intelligibility under these conditions is related to the ratio of direct sound to indirect sound. As the listener moves away from the loudspeaker, the ratio of direct sound to indirect sound at the listening position decreases, and the intelligibility decreases correspondingly. Hence, in a highly reverberant space the intelligibility decreases with distance from the loudspeaker.

To prevent the sound from becoming unintelligible in a highly reverberant space, several speakers can be installed about the area rather than just one. The power requirements remain the same; one 25-watt speaker could be replaced by 5 speakers, each consuming 5 watts. This would greatly increase the direct-to-indirect sound ratio.

INTERFERENCE.—Two sound waves moving through the same medium at the same time will advance independently, each producing the same disturbance as if it were alone. The resultant of the two waves can be obtained by adding algebraically the ordinates (instantaneous magnitudes) of the component waves.

Two sound waves of the same frequency, in phase with each other and moving in the same direction are additive. The resultant wave is in phase with, and has an amplitude equal to, the sum of the component waves.

Two sound waves of the same frequency, in phase opposition and moving in the same direction, are subtractive. If the component waves have equal amplitudes, the resultant wave is zero. This addition or subtraction of waves is often called interference.

Two sound waves of slightly different frequency and moving in the same direction produce a beat note. If the two waves originate from two vibrating sources at the same point, and the frequency of one wave is one vibration per second greater than that of the other at a particular instant, the sources will produce additive disturbances at some points and subtractive disturbances at some other points on the relative positions of the waves. These changes will continue to occur as long as the sources are kept vibrating.

The resultant wave has a periodic variation in intensity at a frequency equal to the difference between the original frequencies of the component waves. The difference frequency,

referred to as the beat frequency, produces a type of pulsating interference particularly noticeable in sound waves. The effect of beat frequency, called beats, produces alternately loud and soft pulses or throbs. The effect is most pronounced when the component waves have equal amplitudes.

STANDING WAVES.—Two sound waves of equal frequency and amplitude moving in opposite directions through the same medium may produce standing waves. Standing waves are set up by the reaction of the two waves on each other. At certain points they are in phase and at other points they are 180° out of phase. Because their amplitudes are equal, when the two waves act in opposition on a particle, the particle remains motionless. At these points in a standing wave, there is no vibration and the points are called nodes. At the points where the two waves reinforce each other they produce maximum vibrations on a particle. These points are called antinodes. The distance between successive nodes (or antinodes) is a half wavelength.

RESONANCE.—Resonance, or sympathetic vibration, is a common problem encountered in acoustics. It is somewhat more serious than some of the other problems discussed, because the possibility exists for damage to equipment. Reverberation and resonance are frequently confused, but they are distinctly different in nature. Reverberation is a result of the reflection of sound waves and of the interaction between the direct and reflected sound. There is only a single source involved. In resonance, however, the offending object becomes a sound source under certain conditions. This may be explained by the following example:

Assume that the natural frequency of vibration of a steel shaft, which is weighted on one end and held firmly on the other, is 25 vibrations per second. Suppose that with the system at rest, a sound wave produces a force which acts on the shaft with a to-and-fro motion 125 times per second. This force sets the system vibrating at 125 vibrations per second. These vibrations would be of a small amplitude because the rod and weight are trying to vibrate at their natural rate of only 25 vibrations per second. During part of the time the system is resisting the driving force. The motion of the system in this case is called a forced vibration.

If the force is slowed from 125 vibrations per second to its natural frequency of 25 vibrations per second, the amplitude of vibration becomes very large. The amplitude will build up to a point where the driving force is enough to overcome the inertia of the system.

When these conditions exist, the system is said to be in resonance with the driving force, and sound waves are produced by this vibration.

A common example of resonance is found in a crystal oscillator circuit. When an alternating voltage is applied to a crystal that has the same mechanical (resonant) frequency as the applied voltage, it vibrates and only a small applied voltage is needed to sustain vibration. In turn, the crystal generates a relatively large voltage at its resonant frequency.

As stated previously, resonance can cause damage to equipment. For example, a hydraulic line (metal tubing) that is not properly supported could be in resonance with the sound transmitted by the engine or electric motor. This sympathetic vibration could cause the fittings of the hydraulic line to loosen or, eventually, could cause metal fatigue.

CHAPTER 4

OPERATING AND SERVICING GROUND SUPPORT EQUIPMENT

Ground support equipment has become as important to the assigned mission of naval aviation activities as the aircraft itself. Many different types of support equipment are required for handling, servicing, loading, testing, and maintaining aircraft. The majority of this equipment is utilized in direct support of the aircraft; therefore, the aircraft squadron is one of its principal users. Another principal user of certain types of support equipment is the Air Department aboard aircraft carriers. Within this department, personnel of the flight deck and hangar deck aircraft handling crews utilize such aircraft handling equipment as tow tractors and spotting dollies. In addition, personnel of the Aircraft Crash, Fire, and Rescue crews utilize such equipment as the MB-5 aircraft firefighting and rescue truck. These users depend upon personnel of the Aviation Support Equipment Technician rating, who are normally assigned to Intermediate maintenance activities, for the maintenance of this equipment.

Support equipment is usually operated by personnel of the using activity. Since such activities as aircraft squadrons and carrier Air Departments are the principal users, the equipment is usually operated by personnel of ratings other than AS. In addition, such maintenance as servicing and performing preoperational inspections is frequently accomplished by personnel of these using activities. Thus, the AS rating is concerned primarily with major inspections and repair. However, this does not mean that personnel of the AS rating are relieved of all responsibilities concerning the operation and servicing of the equipment. In fact, the ASH, as well as the ASE and ASM, should be experts in these procedures. To effectively perform all phases of maintenance—inspecting, troubleshooting, repairing, testing, etc.—the ASH must understand thoroughly the operation of the equipment. This is especially important when troubleshooting malfunctions and testing equipment.

In addition, the ASH is frequently called upon to check out squadron personnel in the operation and servicing of certain types of equipment. Several types of support equipment require licensed operators. The procedures for training, testing, and licensing of these operators are also responsibilities of the Aviation Support Equipment Technician rating.

The first part of this chapter introduces some representative items of various types of support equipment which are the maintenance responsibility of the Aviation Support Equipment Technician rating in general. Specific areas of responsibility of the ASH3 and ASH2 are indicated.

Obviously, it is impossible to relate detailed operating procedures for all types of support equipment in the scope of this training manual. Examples are given on some of the equipment described in this chapter. The operating and servicing procedures for those equipments which are primarily the responsibility of the ASH are described in the respective chapters of this manual. It must be emphasized, however, that this is a training manual for support equipment in general and that the applicable Operation and Service Instructions for a specific item of equipment must be consulted for the correct operating and servicing procedures.

Included in this chapter is a section on the types and designations of fuel, oil, hydraulic fluid, lubricants, and coolants used in the servicing of support equipment. Also included are sections concerning preoperational inspections and general safety precautions that must be observed around support equipment.

TYPES OF GROUND SUPPORT EQUIPMENT

For the purpose of maintenance functions and responsibilities, ground support equipment is classified into five major categories.

1. Avionics support equipment

2. Gasoline, electric, and diesel powered servicing equipment.
3. Gas turbine powered servicing equipment.
4. Trailers, dollies, and carts (nonpowered).
5. Miscellaneous support equipment.

The first category, avionics support equipment, pertains to the equipment required to maintain and test avionic systems and components. The maintenance of this equipment is the responsibility of avionics personnel (AT, AQ, AX, etc.). With the exception of a few items of equipment, the remaining four categories are the maintenance responsibility of the AS rating and are described in the following sections.

GASOLINE, ELECTRIC, AND DIESEL POWERED SERVICING EQUIPMENT

This category includes those types of support equipment which are powered with diesel or gasoline driven engines or with electricity. (This category does not include turbine powered equipment.) Such equipment as tow tractors, weapons loaders, mobile electric powerplants, air conditioners, hydraulic test stands, air compressors, and steam cleaners are included in this category. Some representative types of powered servicing equipment are described in the following paragraphs.

Tow Tractors

The tow tractor is the only means of propulsion for the majority of aircraft when the aircraft is on the ground and the engines are not running. Most present day aircraft are too heavy and large to be moved by manpower alone. Tow tractors are also used for towing trailer mounted support equipment.

Tow tractors must be especially maneuverable, particularly those used on aircraft carriers. Maneuverability of the tractor depends on its dimensions and turning radius. The smaller the dimensions and turning radius the more maneuverable the tractor will be. The type of transmission may also contribute to the ease of handling of the tractor. Modern tow tractors are usually equipped with automatic transmissions. Compared with the standard transmission, the automatic transmission provides a smoother coupling from the engine to the driving wheels. It also frees the driver from operating a clutch and allows him to concentrate more on the job at hand. This results in smoother and safer movement of aircraft and equipment.

Tow tractors are often rated by drawbar pull. The drawbar pull is the amount of force that the tractor can exert. The drawbar pull of any tractor is dependent on the type and condition of the surface on which it is being used. Dry concrete gives the most traction; hence the most drawbar pull for a given tractor. On a wet, fuel soaked steel or wooden flight deck, the traction may be almost nil.

Support equipment for supplying electric power and/or compressed air for aircraft engine starting or servicing is installed on some tractors.

The ASH is responsible for the inspection, maintenance, and repair of the brakes and brake systems, the tires and wheels, the chassis and frame, and all other structural members of the tow tractor.

Tow tractors are usually classified by one of two designations—the M series and the TA series. Some tractors may have both designations. The first two letters of the M series do not have a standard meaning. The number in the M series is the model number. A letter following the model number indicates the number of modifications to that model tractor. An A indicates the first modification, a B indicates the second modification, etc. The TA in the TA series denotes Tractor Aircraft. The numbers following the TA indicate the first two numbers of the drawbar pull. Other designations are sometimes used to identify tractors. One example is the JG-75 tow tractor. This tractor, however, is one model of the TA-75, which is discussed later.

All tractors classified as a certain type are not always manufactured by the same contractor. As a result, the tractors may not be identical in all respects. They may differ in appearance. The instruments and control may be arranged differently. Such major components as the engines and transmissions may be manufactured by different companies. However, these tractors are still classified as the same type as long as they meet the Military Specifications for that type. The same is true for many other types of support equipment. This is another important reason why all personnel of the AS rating should consult the applicable technical publications to properly and safely operate, service, and maintain each specific item of support equipment.

As indicated by the preceding discussion, there are several types and models of tractors available to aviation activities. The tractors described in the following paragraphs are representative of the types most widely used at the present time.

TA-18 TOW TRACTOR.—This is a gasoline powered tractor for use on shore bases as an aircraft towing and spotting vehicle for large aircraft. This tractor has a drawbar pull of 18,000 pounds.

The TA-18, shown in figure 4-1, has an automatic transmission with 6 forward speeds and 1 reverse speed. The speed ranges are selected by a shift lever located on top of the transmission cover. The transmission shift pattern is shown in figure 4-2. The tractor dimensions are 14 feet 10 inches long, 8 feet wide, and 5 feet 7 inches high. The turning radius is 24 feet 10 inches. The gross weight of this tractor is 25,800 pounds. Normally, the driver's compartment is open, as shown in figure 4-1; but if the tractor is to be used in cold weather, it can be obtained with a completely enclosed cab. These cabs are equipped with windshield wipers, heater, and defroster.

TA-75 TOW TRACTOR.—The TA-75 is a gasoline powered tractor intended for use on shore bases as a towing and spotting vehicle for aircraft with gross weights up to 75,000 pounds. This tractor has a drawbar pull of 7,500 pounds.

NOTE: The maximum safe towing weight for a tow tractor can be calculated by multiplying the rated drawbar pull by 10. For example, the rated drawbar pull of the TA-75 tractor is 7,500 pounds. By multiplying 7,500 pounds by 10, we find this tractor can be used to safely tow aircraft with a gross weight up to 75,000 pounds.

The TA-75 (fig. 4-1) has provisions for mounting a gas turbine compressor or other servicing equipment. It is equipped with an automatic transmission that has three forward speeds and one reverse speed. The speeds are selected by a pushbutton control located on the dash panel. The tractor dimensions are 10 feet long, 5 feet 6 inches wide, and 3 feet 9 inches high. The turning radius is 10 feet. The gross weight is 10,500 pounds.

MRS-190 TOW TRACTOR.—The MRS-190 tow tractor (fig. 4-1) is intended for use at air stations for positioning aircraft arresting gear. This tractor weighs 47,000 pounds and is capable of exerting sufficient drawbar pull to perform practically any work that may be required. It is 17 feet long and 9 feet 6 inches wide. It is powered by a 355-horsepower diesel engine and is equipped with a 5-speed standard transmission.

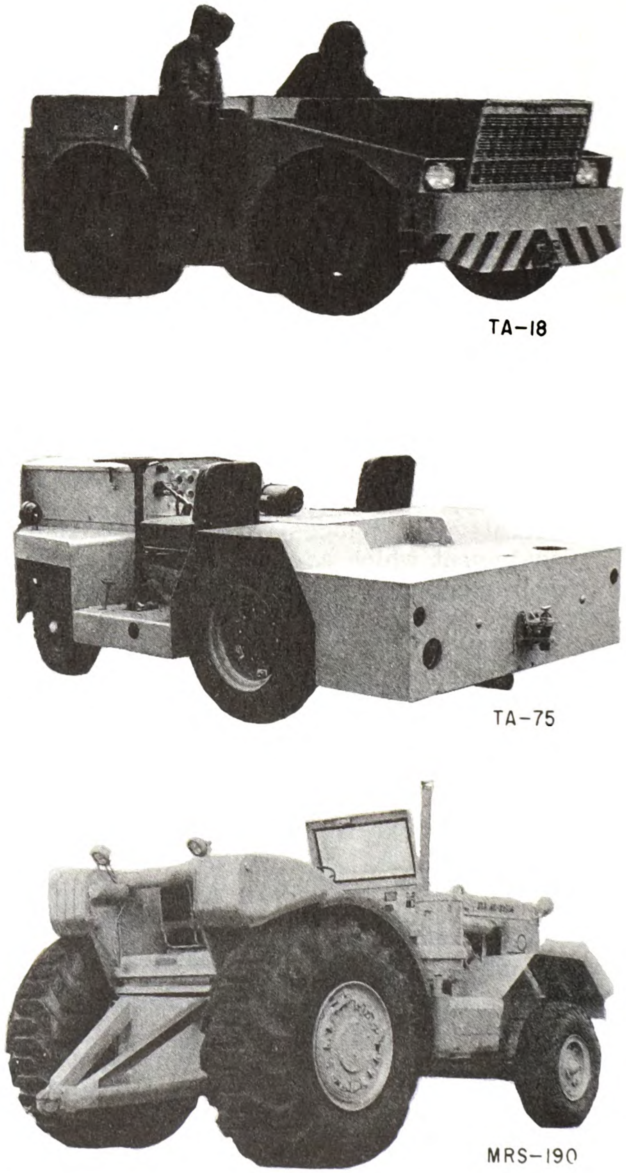

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Figure 4-1.—Tow tractors.

MD-3 TOW TRACTOR.—This tractor was designed for use aboard aircraft carriers and will handle any type of carrier-based aircraft. The MD-3 tractor, illustrated in figure 4-3, is

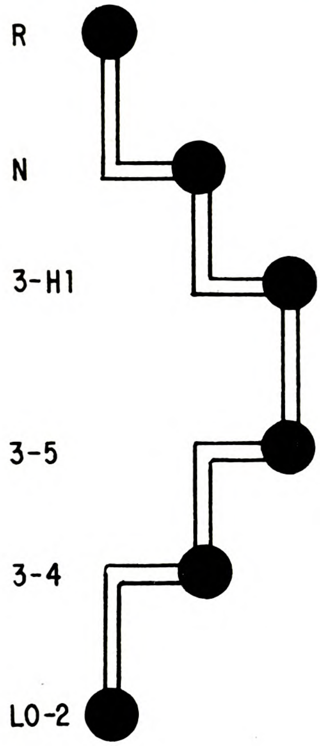

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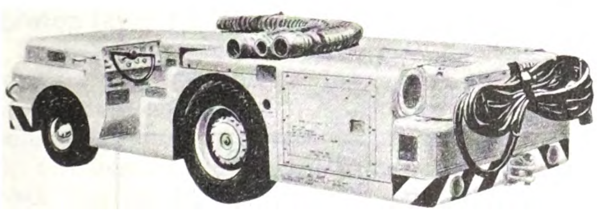
Figure 4-2.—TA-18 transmission shift pattern.



AB.255
Figure 4-3.—MD-3 tow tractor.

replacing the older MD-1, MD-1A, and MB-1 tractors.

The MD-3 tow tractor is a self-contained unit capable of developing 8,500 pounds draw-bar pull at an approximate speed of 1 mph on a dry, level concrete surface. The main power-plant of this type tractor is an inline horizontal, four stroke cycle, internal combustion type diesel engine. The steering system is hydraulically assisted, and the service brakes are assisted by compressed air. The gross weight of the MD-3 tractor is 12,000 pounds.

The transmission is a multiple reduction drive unit that shifts automatically in all forward gear ratios. It is bolted to the engine bell housing and is driven through a single-stage torque converter. A hydraulic control system regulates the transmission shifts. The system also synchronizes the engagement and release of the control clutches and brake bands to effect quick position shifts to meet load demands. The complete transmission system is lubricated, operated, and cooled by a single oil system.

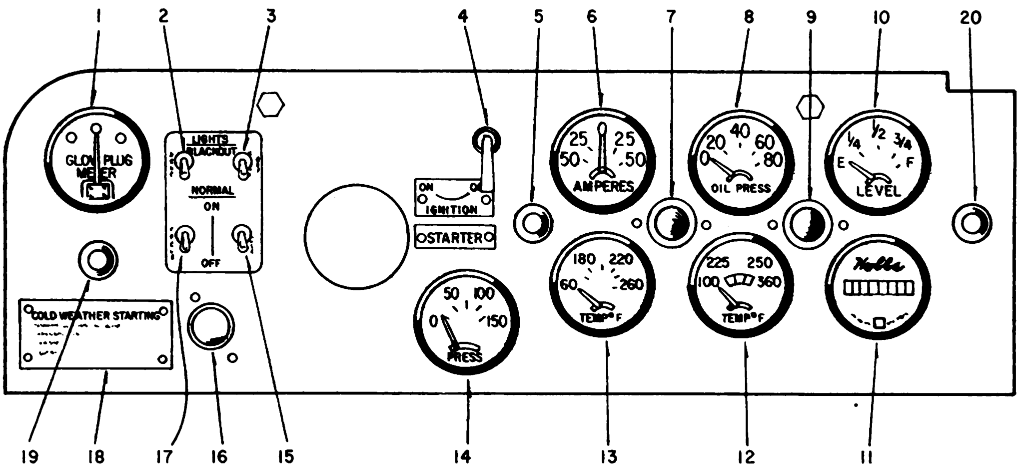
A gas turbine compressor mounted at the rear of the tractor provides pneumatic power in the form of compressed air for the operation of large class pneumatic equipment, such as aircraft main engine starters, air-conditioning systems, and other consumers of compressed air. The operating controls for the gas turbine compressor are located on a panel on the right-hand side of the operator's compartment. Compressor operation is outlined on two instruction plates adjacent to the controls.

OPERATION OF TOW TRACTORS.—The ASH is required to operate tractors when training personnel, troubleshooting malfunctions, and testing after repairs have been made. As mentioned previously, the operating procedures relative to the various types and models of tow tractors differ in some respects. The operation of the MD-3 is used as a representative example in the following discussion. It should be emphasized that the current applicable Operation Instructions should be consulted for the correct operating procedures relative to the different types and models of tow tractors.

Before attempting to operate any type of equipment, the operator should be familiar with the different instruments and controls. Figure 4-4 shows the arrangement of the instruments and controls, and figure 4-5 shows other controls of one model MD-3 tow tractor.

Procedures for starting the MD-3 tractor depend on weather conditions. If the average ambient temperature is above 40°F, NORMAL starting procedures should be followed. If the average temperature is 40°F or below, COLD WEATHER starting procedures should be followed.

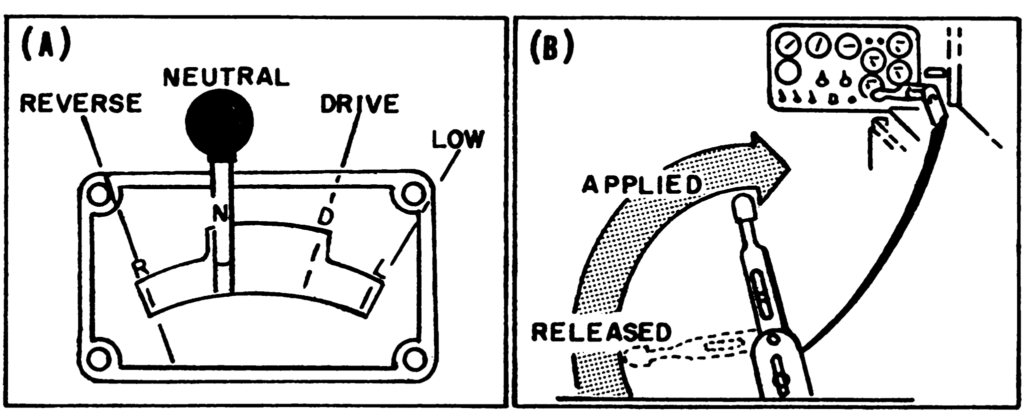
The normal starting procedures are as follows:



AS.672

1. Glow plug meter.
2. Stoplight switch.
3. Headlight switch.
4. Ignition switch.
5. Start switch.
6. Ammeter.
7. Dash lamp.
8. Engine oil pressure gage.
9. Dash lamp.
10. Fuel gage.
11. Hourmeter.
12. Torque converter temperature gage.
13. Engine temperature gage.
14. Air pressure gage.
15. Instrument Light Switch.
16. Air low-pressure warning light.
17. Pintle light switch.
18. Instruction plate.
19. Glow plug switch.
20. Horn button.

Figure 4-4.—MD-3 instrument/control panel.



AS.214

Figure 4-5.—MD-3 controls. (A) Shift pattern; (B) parking brake lever operation.

1. Apply the hand brake and shift transmission to N (neutral). (See fig. 4-5.)

2. Turn the ignition switch (item 4, fig. 4-4) ON and push the starter button (5) until the engine begins firing regularly. Should the engine fail to start immediately, release the starter button and allow a 2-minute recovery time before making additional attempts to start. Excessive engine cranking at any one time may damage the cranking motor.

3. After the engine starts, check the engine oil pressure (8), water temperature (13), and the operation of the ammeter (6). The ammeter should indicate a positive (+) charging rate.

CAUTION: Stop the engine if there is a sudden rise in engine temperature and/or no oil pressure.

The diesel engine of the MD-3 is equipped with glow plugs for cold weather starting. A glow plug is an electrical heating element installed next to each fuel injector and is used to preheat the injector and combustion chamber. The heating element is supplied with current from the battery. To complete this electrical circuit, the ignition switch (4) and the glow plug switch (19) must be ON. Operation of the glow plug is indicated on the glow plug meter (1). Normal gage operation is indicated by the gage pointer moving to the far right when the glow plug switch is pressed.

Cold weather starting procedures are as follows:

1. Apply the hand brake and shift the transmission lever to N (neutral).

2. Turn the ignition switch (4) ON and press the glow plug switch (19) to preheat the engine combustion chambers. Allow the amount of preheat time as indicated in table 4-1. After the combustion chambers have been warmed, press the starter button. Do not release the glow plug switch until the engine begins firing regularly.

3. If the engine fails to start during the first 30 seconds of cranking, release the starter button to allow a 1-minute recovery period before making additional attempts at starting. Do not release the glow plug switch between start attempts.

4. After the engine starts, run it at a fast idle until the engine oil pressure gage (8) indicates oil circulation and the engine temperature gage (13) indicates that the cooling system is warm. Idle the engine until full air pressure is developed in the brake system. This is indicated by the air pressure gage (14) and the air low-pressure warning light (16). The warning light is on whenever pressure in the air system is less than 60 psi. The tractor should not be operated until the warning light is OFF and the air pressure gage indicates more than 60 psi.

Table 4-1.—Glow plug preheating chart.

Ambient Air temperature °F	Preheating time (minute)
60	0.5
30	1.0
0	1.5
-20	3.0

CAUTION: Do not use glow plugs while the tractor is working. Damage to the engine may result.

To operate the tractor, apply the service brakes and release the parking brake. (See fig. 4-5 (B).) With the engine idling, select the type transmission operation desired with the shift lever. (See view (A), fig. 4-5.) Release pressure on the brake pedal and gradually increase the accelerator feed to start moving the tractor. The transmission should be operated in the following manner.

All normal forward driving and towing with light or moderate loads should be accomplished with the shift lever at D. In this position the transmission will automatically upshift and downshift between second gear and third gear (direct drive). Maximum acceleration is obtained by fully depressing the accelerator, causing the transmission to automatically downshift from third gear to second gear. When pressure on the accelerator is decreased, the transmission will automatically upshift.

The shift lever should be moved to L when the tractor is used to tow near maximum loads (8,500 pounds drawbar pull), ascend steep grades or pull through sand, mud, or snow. In addition, engine braking power can be gained when the transmission is in this gear ratio. This braking power assists the braking action of the service brakes. The transmission will

not upshift automatically from first gear while the lever remains at the L position.

The shift lever may be moved from L to D or from D to L at any tractor speed. If the shift lever is at D when the tractor is at a standstill and the accelerator is fully depressed, the transmission will automatically downshift from second gear to first gear. As tractor and engine speed increases, the transmission will automatically shift from first gear through second to third gear.

The tractor must be brought to a complete stop before making the shift between D and R. When the tractor must be rocked back and forth, maintain a steady but moderate pressure on the accelerator pedal and move the shift lever back and forth between D and R.

During tractor operation, the operator should listen for unusual sounds which may indicate trouble. Gages and instruments should be checked periodically. Any unusual gage indications, such as excessive temperatures or pressures, are warnings of possible troubles. For example, the torque converter temperature gage (item 12, fig. 4-4) shows the temperature of oil leaving the converter. Readings will vary with working conditions, but the converter temperature should never exceed 250°F.

AIRCRAFT SPOTTING DOLLY

The movement of aircraft on the ground and aboard aircraft carriers has historically been accomplished by means of tow bar and manpower or tow bar and tractor; however, in crowded areas these methods become ineffective. The aircraft spotting dolly (fig. 4-6) can, while providing maximum maneuverability, tow, turn, and spot several types of aircraft, equally as effective in congested areas as in the open.

At the time of this writing there are two models of spotting dollies in operation. The older model is identified as the SD-1C and the newer model as the SD-1D. Both models are manufactured by Consolidated Diesel Electric Corporation. The two models differ to some extent. For example, the SD-1C is equipped with a 4-cylinder engine, weighs 5,500 pounds, and provides a 28-volt, 40-ampere, d-c output to supply aircraft needs during spotting operations. The SD-1D is equipped with a 3-cylinder engine and weighs 7,500 pounds. It is not

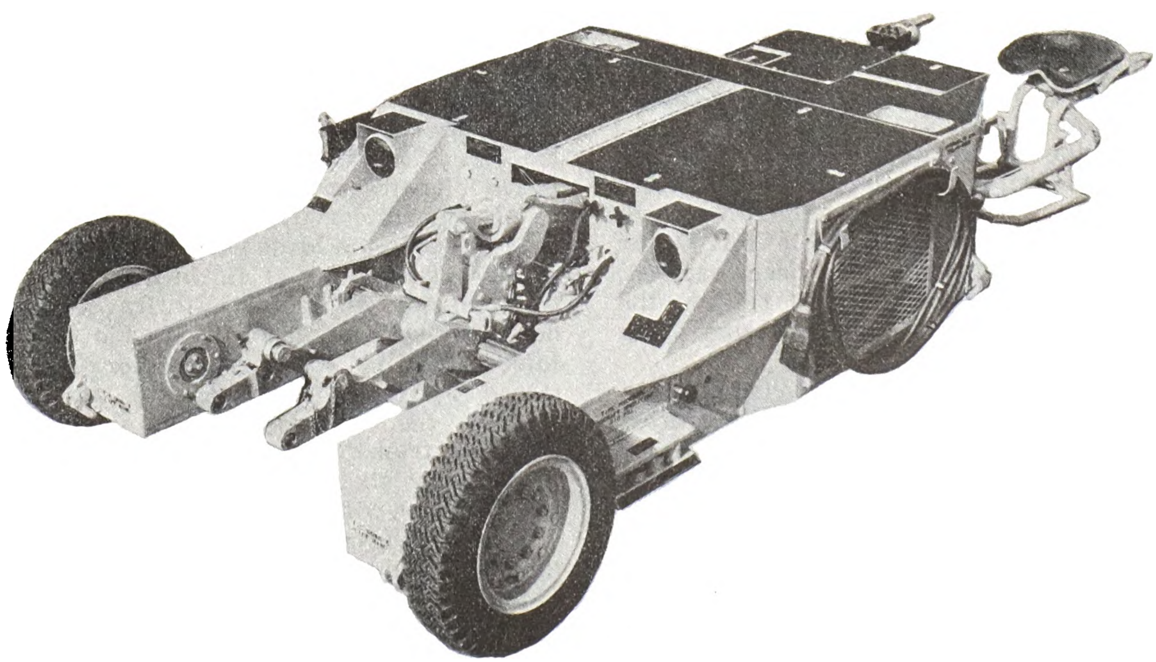


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Figure 4-6.—Aircraft Spotting Dolly.

equipped to provide d-c power to the aircraft. In addition, several of the major components of the two models are manufactured by different companies. The two models are, however, quite similar in appearance and operation.

The aircraft spotting dolly is powered by a 3- or 4-cylinder, water-cooled diesel engine. This provides the spotting dolly with 6,000 pounds drawbar pull and 16,000 pounds of lift. It may be operated under most aircraft, since its height is only 29 inches.

Self-propelled, the spotting dolly moves an aircraft by picking up the nosewheel and moving the aircraft in any direction, with no turning radius required by the spotting dolly. The spotting dolly can approach an aircraft head on, pick up the nosewheel, spin on its own axis, and tow the nosewheel directly out at any angle to the aircraft's original line of direction. It can turn an aircraft through 360 degrees while the center of the landing gear remains stationary.

The nosewheel, when loaded on the lifting arms of the spotting dolly, is on a freely revolving turntable located between the two drive wheels of the spotting dolly. A differential drive system permits one drive wheel of the spotting dolly to be driven forward, the other in reverse. This allows the spotting dolly to spin completely about without moving the nosewheel.

The spotting dolly is a 3-wheeled device, two of the wheels being driven and the third, a free-wheeling caster. Control is accomplished through a single handle on the end of the control arm. Steering is accomplished by pushing the handle left or right; speed and direction (forward or reverse) by twisting the handle. The operator may either walk with the unit, or ride on the operator's seat, controlling it with a single hand. Maximum speed for the SD-1C is 5 miles per hour loaded, and 10 miles per hour unloaded. For the SD-1D, the maximum speed is 2 miles per hour loaded, and 5 miles per hour unloaded.

The usual manner of loading an aircraft is to set the brakes on the main landing gear, lower the lifting arms, drive the spotting dolly under the nosewheel, insert two axle pins in the lifting arms, raise the lifting arms, release the aircraft brakes and drive away.

The hydraulic system of the spotting dolly is described in chapter 14 of this training manual.

WEAPONS LOADERS

Many different means have been used to transport aerial weapons to the aircraft and to load these weapons on the aircraft. The latest devices designed for this purpose are the AERO 46 and AERO 47 weapons loaders. The latest models of these loaders are the AERO 46A and AERO 46A1 for use on aircraft carriers and the AERO 47A and AERO 47A1 for use on shore bases. These weapons loaders are similar in design and operation. The AERO 47A is described in the following paragraphs.

The AERO 47A Weapons Loader (fig. 4-7) is designed primarily for the U.S. Navy to load externally carried munitions, weapons, jato bottles, ammunition cans, rockets, pylons, and fuel tanks onto tactical aircraft. It is used to lift, transport, and attach these items of varying size, weighing up to 4,500 pounds, to the wing and centerline pylons of the aircraft. All lifting and manipulating functions of the weapons loader are hydraulically powered. The vehicle is powered with a 27.5 horsepower, multifuel burning engine which provides power for the movement of the vehicle as well as the hydraulic system.

The Aero 47A is controlled in a manner similar to conventional forklift trucks. It is equipped with hydraulic powered steering which provides a turning radius of 15 feet. All hydraulic motions, including the lifting mechanism, incorporate safety features which prevent movement of the load in the event of mechanical or hydraulic failure.

The application of this loader in aircraft loading operations permits the loading of all weapons with a 2-man crew. Since the loader permits transportation and handling of prepackaged multiple suspension racks, operations such as individual weapon attachment, sway bracing, fuzing, attaching arming wires, and preliminary rack checkout can be performed as a prestaging operation. Loading time at the aircraft is reduced to an absolute minimum.

The Aero 47A has conventional automotive power steering. The drive train consists of a single disc, dry automotive clutch, a standard 3-speed transmission, a 2-speed transfer case, and a limited slip differential to insure positive traction. Brakes consist of a mechanical parking brake on the rear wheels and hydraulic service brakes on the rear wheels and two inside front wheels.

The hydraulic systems of weapons loaders are discussed in chapter 14 of this manual.

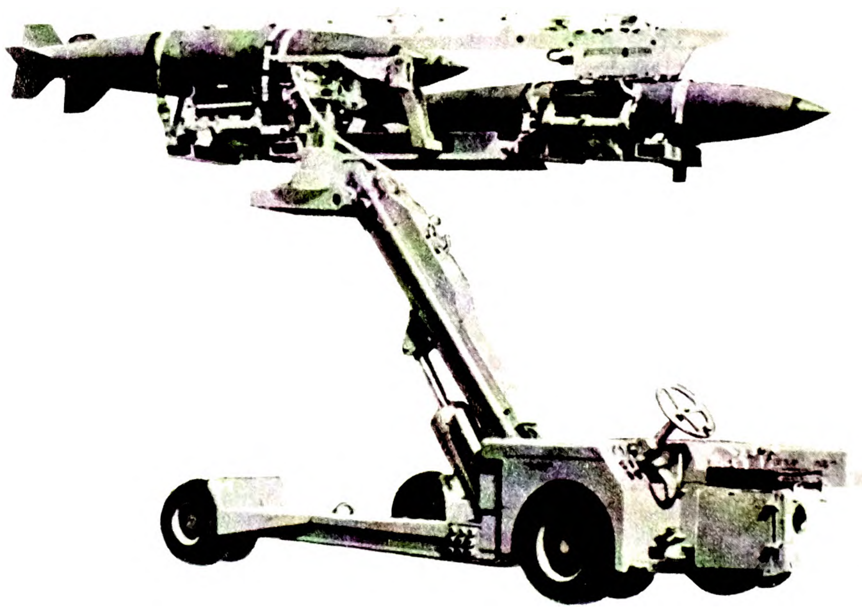

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Figure 4-7.—Aero 47A Weapons Loader.

MOBILE CRANES

Mobile cranes are used both at shore stations and aboard ship. Those for shipboard use are usually smaller and to some degree more maneuverable than shore based cranes. The mobile crane is an emergency vehicle primarily designed for use in aircraft salvage and rescue.

Maximum performance of the mobile crane, including its operating equipment, is dependent upon the frequency and scope of the maintenance rendered plus the ability of the operator to properly operate the crane. Personnel must be thoroughly familiar with the contents of the applicable technical manual before attempting to operate a crane.

The NS-50 and NS-60 Mobile Cranes are designed primarily to lift and carry crashed aircraft on the flight deck of an aircraft carrier, and are equally suitable for similar duty on shore stations for both aircraft landing areas or unpaved areas. The NS-50 and NS-60 are quite similar in appearance and in operation, the basic difference being in the greater length of the boom and lifting capacity of the NS-60. For purpose of discussion, the NS-50 is described in the following paragraphs. The NS-50 is illustrated in figure 4-8.

This crane, a self-propelled vehicle, is mounted on four electrically powered wheels. Heavy-duty d-c electric traction motors and gear reduction units built within the wheel rims provide motive power for the crane. Each wheel motor is equipped with multiple disc type spring-loaded brakes for emergency stops and parking, while a regenerated electrical braking system is used for operational deceleration of the crane.

Gear motors power the boom, hook, and steering. A-c electric motors, strategically located at the point of power application, drive through gearboxes to power each crane function. Each a-c motor is equipped with a multiple disc, spring-loaded brake that sets instantly when the motor's electrical power is interrupted. Restoration of the motor's electrical power automatically releases the motor brake.

A-c and d-c generators, directly coupled to the diesel engine, supply current to the control

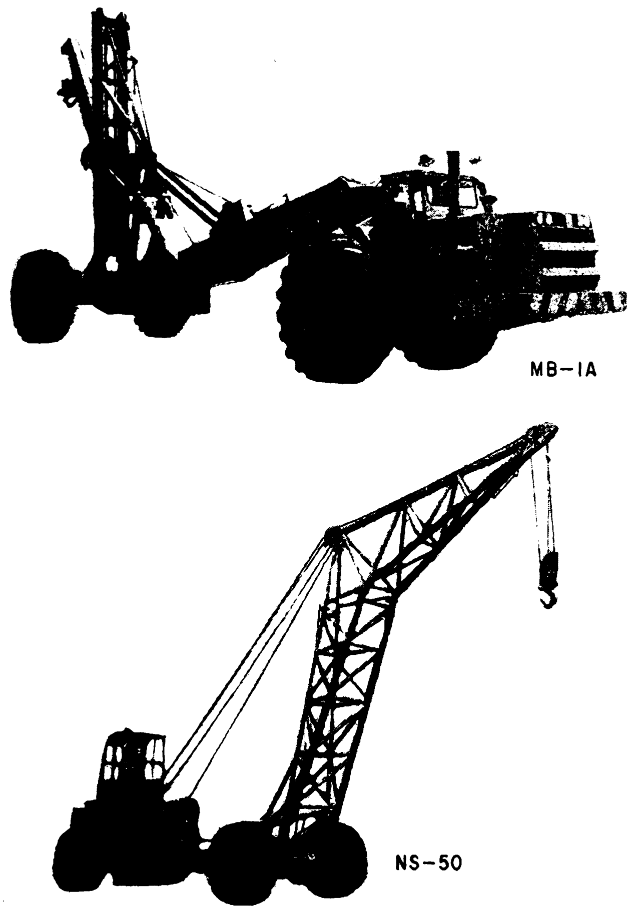

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Figure 4-8.—Mobile cranes.

motors and to the d-c drive motors. Fingertip switches on the operator's panel control the application of power to the a-c motors. One control handle on the panel provides power and directional control to the electric wheels, while another gives the operator complete motor braking control.

All normal operations required for maneuverability of the crane are managed from the operator's station. A remote control panel on the rear of the crane permits control of the hook and boom at a point near the load.

The crane is 40 feet long without the boom. With the boom extended 23 feet, the overall length is 64 feet 9 inches. The overall height is 33 feet with the boom extended. The turning radius is 35 feet. The gross weight of the crane is 72,300 pounds.

The crane is capable of lifting 50,000 pounds when its boom is positioned anywhere between its minimum and 23-foot outreach. The crane is also capable of exerting a drawbar pull of 42,000 pounds for towing operations.

The MB-1A mobile crane (fig. 4-8) is designed primarily for lifting, maneuvering, and removing crashed aircraft from air station runways and surrounding areas. The MB-1A is made up of a 2-wheel vehicle (prime mover) attached to a 2-wheel crane.

The prime mover is powered by a diesel engine driving through a twin-disc clutch, a 5-speed transmission, a high/low speed auxiliary transmission, and a torque-proportioning differential. The auxiliary transmission in combination with the 5-speed transmission results in 10 speeds forward and 2 speeds in reverse. The wheels of the crane are not powered.

An a-c generator, driven from the engine flywheel, supplies current for powering the hook motor, jib motor, boom motor, and the steering motor. These motors are controlled by fingertip switches located at the operator's station. A remote control box is provided for controlling the hook, jib, and boom motors from a position near the point of pickup.

MB-5 AIRCRAFT FIREFIGHTING AND RESCUE TRUCK

Most aircraft firefighting and rescue equipment used on shore stations is maintained by the Public Works Department. On board aircraft carriers, personnel of the AS rating are concerned with the maintenance of this type equipment. An example of such equipment is the MB-5 Aircraft Firefighting and Rescue Truck.

Different models of the MB-5 have been used on shore stations for several years. Recently, a late model of the MB-5, manufactured by the Oshkosh Truck Corporation, has been proven very successful as a crash, fire, and rescue vehicle on board aircraft carriers. This vehicle provides a means of storing, transporting, and dispensing water, chemical foam, and dry chemical fire control products. It is outfitted with an auxiliary generator which furnishes 110-volt alternating current for power tools used in rescue operations. The vehicle cab accommodates the normal complement of

four men, and the vehicle is provided with the conventional firefighting tools and equipment for use by the crew during aircraft crash, fire, and rescue operations. This model MB-5 (fig. 4-9) is described in the following paragraphs.

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Figure 4-9.—MB-5 Aircraft Firefighting and Rescue Truck.

The MB-5 operates as a self-contained unit and does not require any accessories or material other than that which it carries to perform its normal functions. The personnel cab is insulated and is provided with a fuel-burning heater for cold weather operations. Various compartments and mounting facilities are provided for the storage and transport of the necessary firefighting equipment.

The main powerplant, which is located on the rear of the chassis, is a 6-cylinder, four stroke, turbo-charged, diesel engine. A torque converter is mounted on the engine and is driven by the engine fly wheel. The torque converter acts as a fluid coupling during normal operation and provides a means of increasing engine torque during peak load conditions. The torque converter provides three output shafts. The center shaft provides driving power to the transmission and the outer shafts drive the turret foam pump and the handline pump.

The transmission is semiautomatic and provides four speeds forward, neutral, and one reverse speed. The transmission gear selector is located to the right of the driver's seat. Under normal conditions, the vehicle can be operated in 4th gear. In this position the transmission will automatically upshift and downshift with the increase and decrease of engine speed. For off-road or heavy pulling operation, a lower gear range should be selected. With the selector in one of the lower gears, the tachometer should be observed for indicated engine speed. When the engine speed reaches 2,200 rpm, the transmission should be shifted to the next higher gear range. A smooth shift can be obtained if the accelerator is released momentarily while shifting. The lower ranges are also used to aid in braking the vehicle when descending steep grades. However, engine speed should not be allowed to exceed 2,500 rpm. The brakes should be applied as necessary to maintain engine speed below the 2,500 rpm level.

The transmission transmits power to both the front and rear axles through separate drive shafts. A parking brake of the internal expanding type is provided on the output shaft to the front axle.

The MB-5 is equipped with power-assisted steering. The service brakes are of the hydraulic type and the system incorporates an air-over-hydraulic power assist unit. The volume of compressed air necessary for the operation of the brakes, windshield wiper, and various other control units is supplied from two reservoirs mounted on the chassis. A constant pressure is maintained in these reservoirs by an air compressor which is mounted to and driven by the engine. A recharging valve is provided on one of the reservoirs to facilitate air system charging from an external supply.

An auxiliary power generator set is located on the work deck area just forward of the main engine. The generator set consists of a one-cylinder air cooled diesel engine coupled to a generator of 1,000-watt capacity. The generator will supply 115-volt, single phase, 60-hertz current for the operation of hand power tools and accessories and will also supply direct current for battery charging. The generator set may be started from the operator's cab by means of an electrical starting motor. A duplicate set of starting switches is provided for starting at the unit. A means of manual starting is also provided.

Maintenance of the MB-5 requires the coordinated efforts of the using and supporting activities. On board aircraft carriers, the

using activity is the V-1 Division of the Air Department and the supporting activity is the Aircraft Intermediate Maintenance Department (AIMD). Within the V-1 Division, personnel of the ABH rating operate the vehicle. In addition to servicing and performing preoperational inspections, personnel of the V-1 Division are responsible for complete maintenance of the actual firefighting equipment and components. AS personnel of the AIMD are responsible for calendar inspection and major repair of the vehicle itself. The ASH is concerned primarily with the inspection, maintenance, and repair of the brakes and brake system, the tires and wheels, the pneumatic system, the chassis and frame, and other structural members of the vehicle.

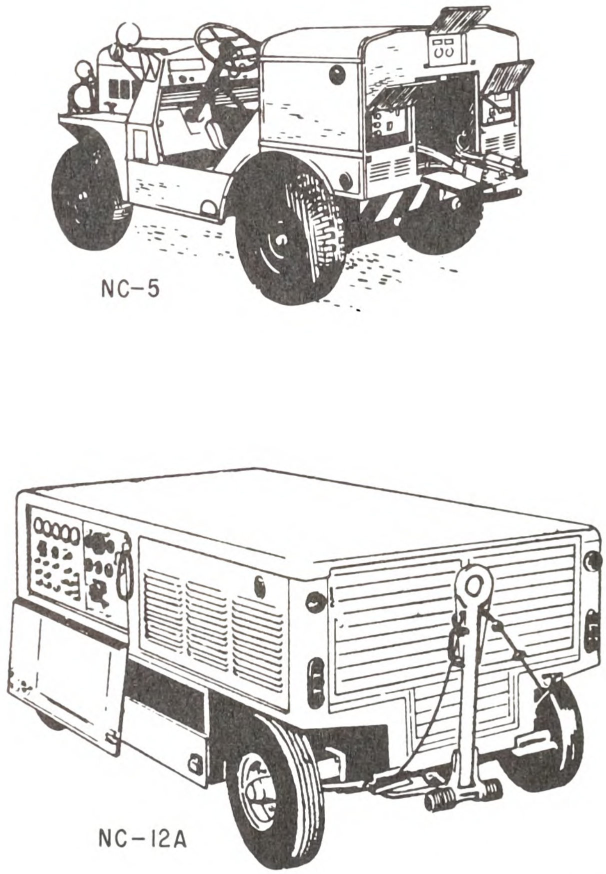

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Figure 4-10.—Mobile electric powerplants.

MOBILE ELECTRICAL POWER PLANTS

Mobile electrical powerplants (MEPP's) supply electrical power for various testing and checkout operations of aircraft. The MEPP's used today are designed for operation on shore stations and aboard aircraft carriers. On aircraft carriers these units are usually of the mobile type, with minimum vehicular dimensions and weight; they are usually designed for utmost maneuverability and mobility. On shore stations, these units may be mobile, large in size, or may be trailer mounted and require towing.

There are many types of MEPP's in use. The type used depends upon the type aircraft to be serviced. Three of the various types of MEPP's are described briefly in the following paragraphs. Although these units are primarily the maintenance responsibility of the ASE and the ASM, the ASH is responsible for the inspection, maintenance, and repair of brakes and brake systems, tires and wheels, and all structural components.

NC-5 Powerplant

This MEPP is self-propelled and may be driven from place to place in the same manner as any other motor vehicle. (See fig. 4-10.) It has provisions for delivering three different kinds of power, each through a separate cable. It will deliver d-c power for servicing purposes. It will also deliver sufficient d-c power for starting jet engines, but only for 1 minute at a time. Both servicing and starting power are taken from the same generator; however, this generator will deliver only one type of power at a time.

In addition to d-c servicing and starting power, the NC-5 will deliver a-c power for servicing a-c equipment in the aircraft and rectified d-c power for servicing during the starting cycle.

The NC-5, being a self-propelled unit, should be treated with as much care as an automobile. Servicing materials and procedures are similar to those for tow tractors. The NC-5 should be operated only by a qualified and authorized operator.

NC-12 and NC-12A Powerplants

The NC-12 and NC-12A are diesel-driven powerplants, designed to supply sufficient power for servicing, starting, and maintaining helicopters and jet aircraft. The units utilize dual electrical power output circuits which make them capable of delivering power for two aircraft simultaneously.

The powerplant and components are mounted on a 4-wheel trailer, equipped with front wheel brakes which are actuated by a hand lever or the spring-loaded tow bar. These units are not self-propelled and, therefore, must be towed.

The NC-12 and NC-12A are both designed the same, except the NC-12 was designed for shore base operation and is equipped with a 6-cylinder engine. The NC-12A was designed for carriers or shore base installations and is equipped with a V-8 series engine.

The electrical characteristics are the same for both the NC-12 and NC-12A. The NC-12A is illustrated in figure 4-10.

NC-2A Powerplant

The NC-2A (fig. 4-11) is designed primarily for emergency use aboard aircraft carriers. (Normally, deckedge power is used.) It is a self-propelled diesel-engine-powered service unit. It is front axle driven, steered by the two rear wheels and readily maneuverable in congested areas. The front axle is driven by a 28-volt d-c, reversible, variable speed motor, capable of propelling the unit up to 14 mph on level terrain, and has a turning radius of 130 inches.

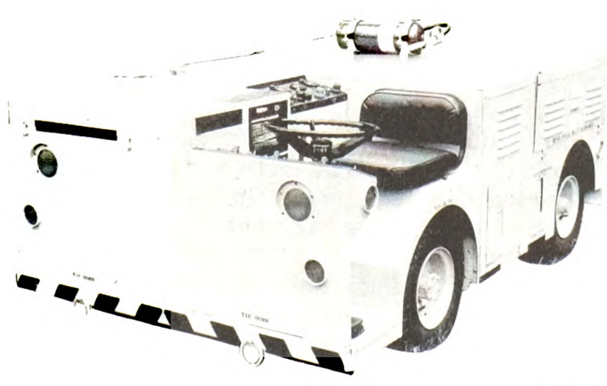

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Figure 4-11.—MEPP NC-2A.

The primary source of power is a 3-cylinder, water cooled diesel engine which drives the a-c and d-c generators through a speed increasing transmission. All controls, both propulsion and electrical power are available to the operator on three panels located in front and to the right of the operator's seat.

The powerplant is designed for air transport and is provided with two tiedown rings each on the front and rear bumpers. Forklift channels are located between the front and rear axles, providing safe lifting points for the unit.

AIR CONDITIONERS

Air-conditioning units are designed to provide ground ventilating and cooling for aircraft cabins and electronic systems. Most units will perform the following functions:

1. Cool aircraft avionics equipment compartments.
2. Ventilate equipment compartments at ambient temperatures where cooling is not required.
3. Cool occupied aircraft cabins.
4. Cool pressurized personnel suits.

Air-conditioning units are usually trailer mounted. The unit is usually powered by either a gasoline or diesel engine. Some models are powered by electric motors. Air-conditioning units are identified by the letter designation NR followed by a model number. NR-1, NR-3, NR-3A, NR-5A, and NR-10 are all different models of air conditioners. The NR-3A and NR-10 are briefly described in the following paragraphs.

The NR-3A air conditioner (fig. 4-12) is a mobile, trailer mounted, self-contained ventilating and cooling unit for air conditioning aircraft cabins and equipment compartments. The unit is powered by a 112-horsepower, 6-cylinder, liquid-cooled engine that drives the compressor, blower, and condenser fan. The engine is equipped with magneto ignition, starter, generator, fuel pump, fuel filter, oil filter, oil bath air cleaner, and coolant pump.

The blower takes filtered air and forces it through the evaporator section, where it is cooled, and through the outlet ducts. The compressor circulates the refrigerant vapor/liquid through the condenser, heat exchanger, and evaporator coil where heat is absorbed from the air circulating by the blower. The condenser fan draws cooling air through the coolant radiator and condenser coils, and forces cooling air over the engine and accessories.

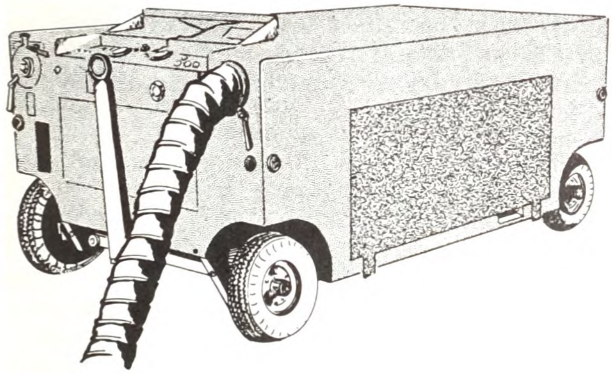

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Figure 4-12.—NR-3A air-conditioning unit.

The NR-10, illustrated in figure 4-13 is a much later model air conditioner. Like the NR-3A, the NR-10 is a mobile, trailer mounted, self-contained air-conditioning unit. The power required for operation of the NR-10 is supplied by a 6-cylinder, 82-horsepower, turbo-charged, liquid-cooled engine. It has a cooling capacity of 19 tons, utilizing a 6-cylinder refrigerant compressor. The refrigerant used is R-22 with a system charge of 90 pounds.

The air-conditioner running gear consists of the brake system and axle assembly. The brake system employs both mechanical and hydraulic braking. Each wheel has an individual brake cylinder. Hydraulic lines are routed from a master brake cylinder installed on the tow bar. The axle assembly consists of the tow bar and four independent suspension wheels. The tow bar assembly is designed to enable overcenter steering of the air conditioner. When the front wheels attain their maximum angular position, a cam on the tow bar assembly is released allowing the tow bar to continue following the motion of the towing vehicle.

The ASE and ASM are primarily responsible for the maintenance of air-conditioning units. Operating procedures vary considerably with different models. Therefore, the Operating Instructions for the specific model must be consulted for the correct operating procedures.

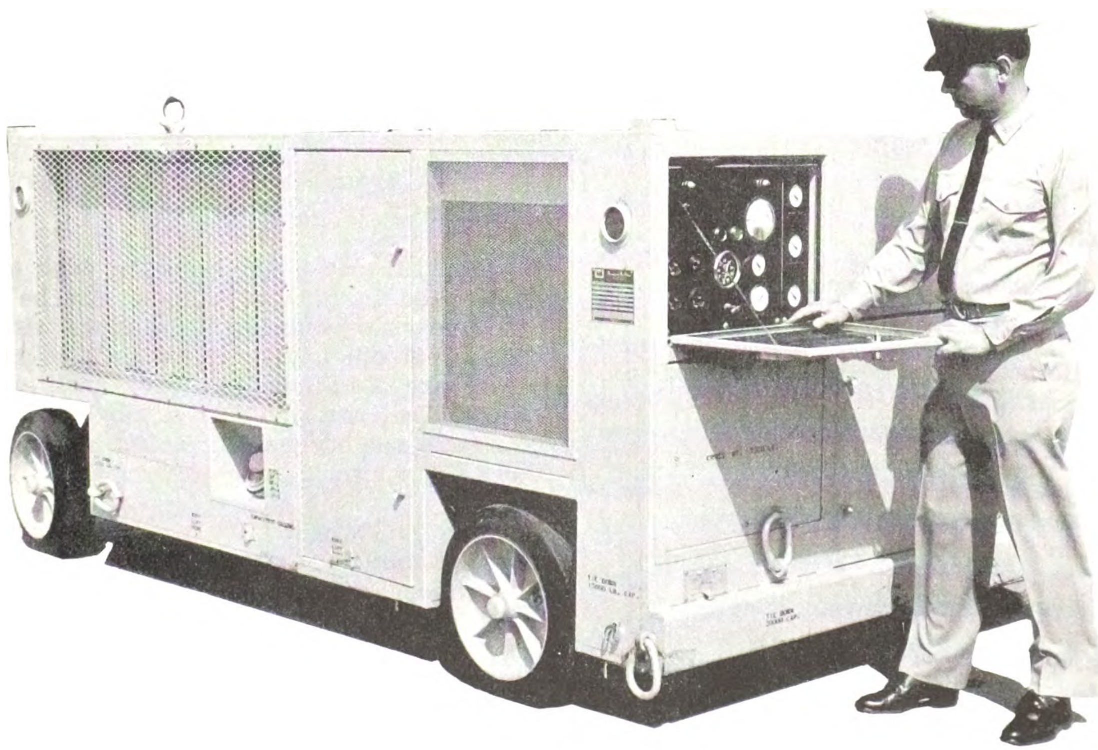

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Figure 4-13.—NR-10 air conditioner.

HYDRAULIC TEST STANDS

Portable hydraulic test stands provide a means of simulating the aircraft engine-driven hydraulic pump. By connecting a test stand to the aircraft's hydraulic system, the various actuating systems may be operated without turning up the aircraft engine. The test stand is connected to the aircraft's hydraulic system at ground test couplings (quick disconnects) provided on the aircraft. In addition to ground checking aircraft hydraulic systems, most test stands can be used for flushing and filling the hydraulic system.

Portable test stands, frequently referred to as hydraulic jennies, may be driven by any of the following means: electric motor, air motor, gasoline engine, or diesel engine. Of these power sources, the electric motor, gasoline engine, and diesel engine are the most widely used. The test stands are mounted on 3- or 4-wheel trailers and are towed or pushed to and from the aircraft.

Obviously, the maintenance of these units is primarily the responsibility of the ASH. Therefore, the operation and maintenance of hydraulic test stands are discussed in chapter 14 of this manual.

Hydraulic test equipment also includes hydraulic test benches. These units are used for testing uninstalled hydraulic components. The description and operation of hydraulic test benches are also covered in chapter 14.

AIR COMPRESSORS

Air compressors supply compressed air for pneumatic powered tools and equipment. Paint spray guns, pneumatic rivet guns, and pneumatic drills receive their power from air compressors. Air compressors also supply compressed air for filling tires and compressed air cylinders. Air compressors are of the portable type or permanently mounted in hangars or shop spaces to supply a constant supply of air. Like many types of support equipment, some types of air compressors are gasoline-engine driven, some are electrically driven, and others are diesel-engine driven. Air compressors are described and illustrated in chapter 13 of this training manual.

FORKLIFT TRUCKS

The forklift truck is a power-driven piece of material handling equipment. It is a cantilever type industrial truck, either gasoline, diesel or electrically powered, having either three or four wheels. It contains vertical uprights and an elevator backplate equipped with two or more forks of sufficient length and thickness for use with various types of pallets. (See fig. 4-14.)

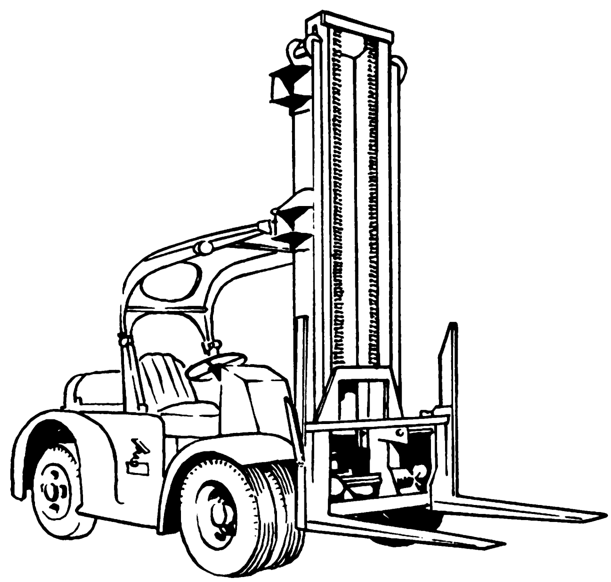

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Figure 4-14.—Forklift truck.

Forklift trucks are generally used to handle palletized unit loads but may also be used to haul boxes or containers equipped with skids, as well as other large containers and packages. They are used to hoist heavy loads into aircraft. They are also used to move loads aboard carriers, on barges, on piers, in warehouses, and in and around freight terminals.

Most forklift trucks that come under the responsibility of the ASH are powered by 4-cylinder gasoline engines. The unit must be operated only by a licensed operator. The servicing and upkeep are similar to that required for other automotive equipment.

Hydraulic power is used for the operation of the fork on many forklifts. Chapter 14 contains a section devoted to the operation and maintenance of a typical forklift hydraulic system.

STEAM CLEANERS

Steam cleaners are used to clean and degrease equipment and components, aircraft, machinery, machine parts, and other items which are not subject to damage through the application of moisture. Most models can be used as a steam cleaner or as a high-pressure hot or cold water washing and rinsing unit. In addition, they are usually equipped with a cleaning solution system whereby soap or other approved cleaning compounds may be automatically mixed with the steam or water.

Steam cleaners are either electrically operated or gasoline-engine driven. An electrically operated model is illustrated in figure 4-15. The operation and maintenance of a gasoline-engine driven model are discussed in chapter 10.

HONING MACHINE

The portable dry honing machine (fig. 4-16) is a compact, self-contained, lightweight, portable unit used for honing small workpieces and for the safe and convenient removal of corrosion products from metal surfaces through the dry honing process. It may be used on equipment and equipment components as well as on aircraft and aircraft components. The machine is air-operated and can be used in shore-based or shipboard operations without loss of materials to the atmosphere.

The maintenance and repair of the dry honer, like the steam cleaner, are primarily the responsibility of the ASH2. Therefore, the operation and maintenance of the dry honer are described in chapter 10.

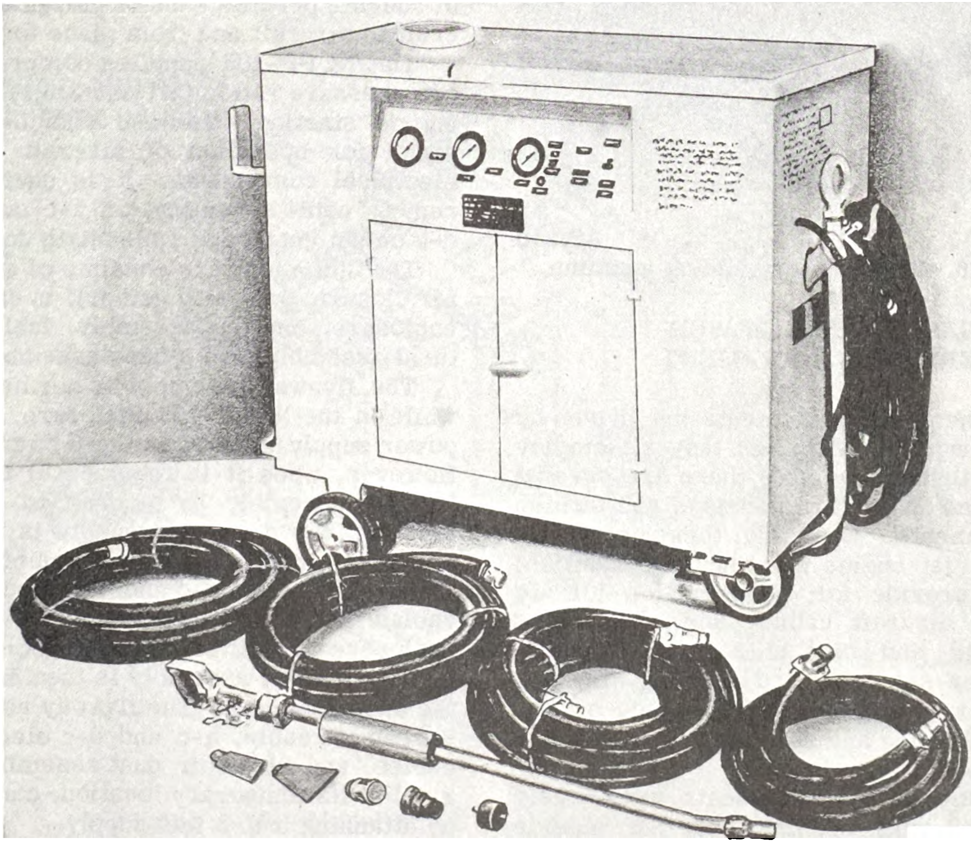

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Figure 4-15.—Steam cleaner.

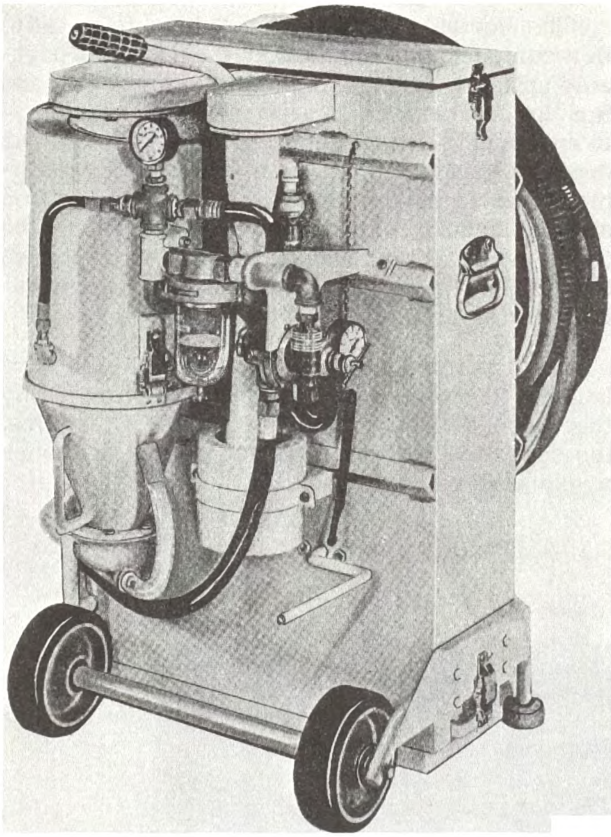

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Figure 4-16.—Portable dry honing machine.

GAS TURBINE POWER SERVICING EQUIPMENT

Gas turbine power equipments are driven by gas turbine engines. Although they all employ similar gas turbine engines, there are several different types and configurations of gas turbine power equipments. Basically, these units provide air for jet engine starting. In addition, some units provide for refrigeration for air conditioning aircraft cabins and electronics compartments, and some units provide electrical power for servicing and starting aircraft. These units may also be used to supply air for safe removal of ice and snow from aircraft and for heating and preheating.

Gas turbine power equipments are largely self-contained and require only an outside source of fuel and oil to maintain a constant output. The units may be enclosed in a skid-mounted enclosure, housed in an aerodynamic pod, or mounted on the rear of a tow tractor, such as the MD-3 described previously in this chapter. When housed in an aerodynamic pod, these units are designed to be transported on the bomb shackles under the wings of jet aircraft. The pod is mounted on detachable wheels or on a bomb trailer when in use. Concerning gas turbine power equipment, the inspection, maintenance, and repair of enclosures are the major responsibilities of the ASH.

GTC-85, GTCP-100, NCPP-105, and RCPP-105 are all different models of gas turbine compressors. The MD-3, described previously, is equipped with the GTCP-100. The NCPP-105 and RCPP-105 are described briefly in the following paragraphs.

The NCPP-105 (fig. 4-17) is a complete, self-contained unit consisting of a flyaway assembly enclosed in a skid-mounted, weather resistant enclosure. The top view of figure 4-17 shows the NCPP-105 as a skid-mounted unit. This unit can be installed on a trailer, as shown in the lower view of figure 4-17. This, of course, permits ease of movement from aircraft to aircraft and from place to place.

The NCPP-105 supplies compressed air, at two pressure ratios (5:1 and 3.6:1), for aircraft engine starting, and a-c and d-c electrical power for operation of aircraft a-c and d-c electrical components. It is equipped with a remote cable assembly, an a-c output cable, a d-c output cable, and a bleed air duct assembly.

The unit enclosure consists of a forward and aft closure (hinged together), a cable stowage enclosure, muffler assembly, fuel tank structural assembly, and a base assembly.

The flyaway assembly is normally operated while in the NCPP-105 enclosure, with the d-c power supply mounted in the forward enclosure. However, when it is required to transport the flyaway assembly by aircraft to a temporary location, the d-c power supply is removed and relocated on the flyaway assembly structure. The fuel line and a-c and d-c electrical output cables are disconnected, the forward and aft enclosures are lifted off the structure assembly, and the flyaway assembly is then removed from the base assembly. The flyaway assembly, with its remote cable, a-c and d-c electrical output cables, and bleed air duct assembly, upon arrival at its temporary location, can be operated by attaching it to a fuel supply.

The control panel is part of the flyaway and is located on one end of the NCPP-105 unit, as shown in figure 4-17. The control panel

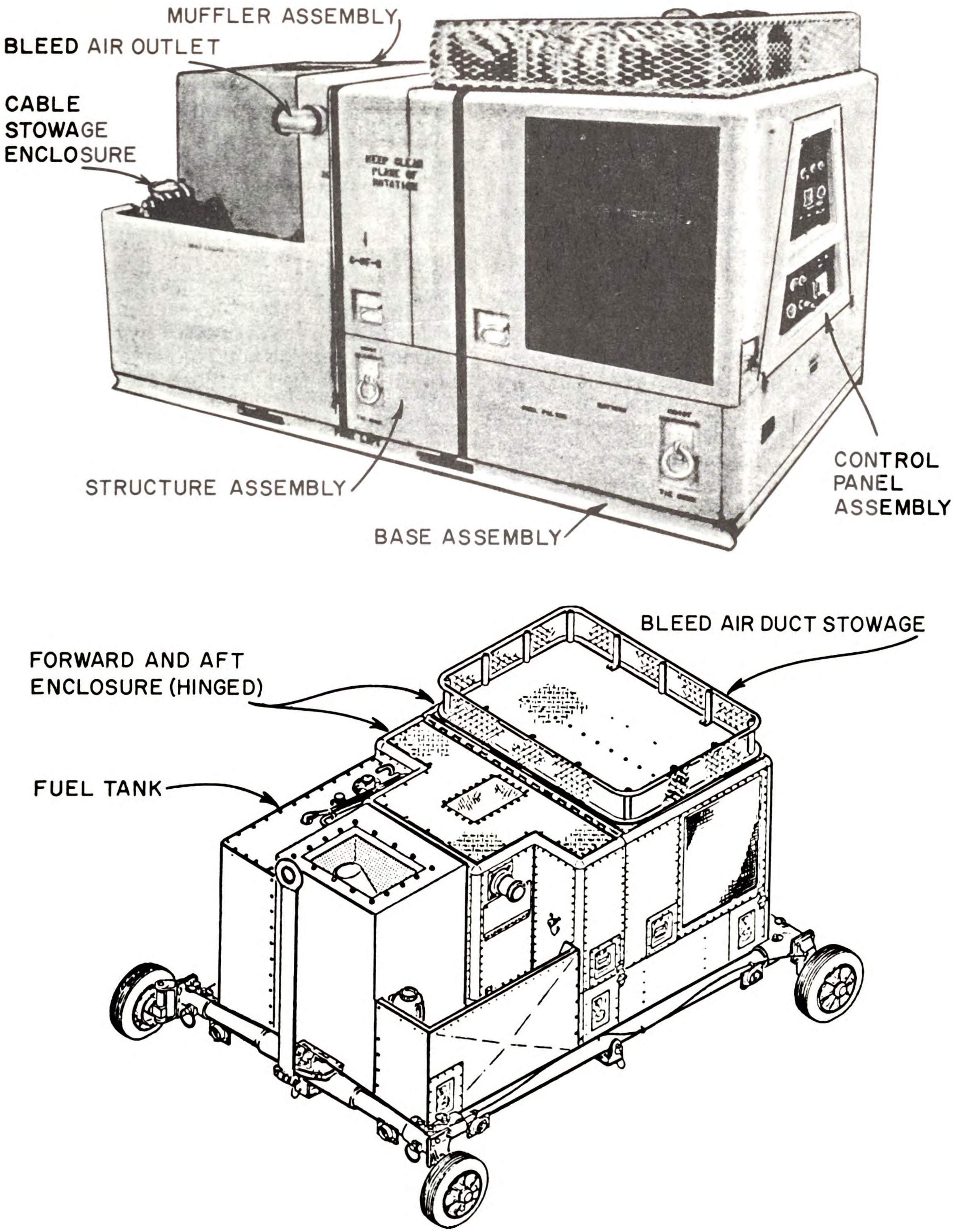

Figure 4-17.—Model NCPP-105 compressor power unit.

contains the complete operating instructions for the operation of the unit.

NOTE: The NCPP-105 flyaway assembly cannot be hung as an external store and must be transported inside a transport or cargo type aircraft.

Figure 4-18 shows the RCPP-105 as it is used to start the F-4 aircraft. This unit was selected to illustrate an example of the aerodynamic pod enclosure. This gas turbine power unit is designed to provide a portable, compact, and self-contained source of compressed air, a-c and d-c electrical power, and conditioned air. Compressed air is available for aircraft engine starting at two pressure ratios, 5 to 1 and 3.6 to 1. Electrical power, either a-c or d-c, is available for the operation of the aircraft electrical system.

Two conditioned air connections provide compartment cooling and pressure suit ventilation air. Hose and cable assemblies for interconnection between the pod and aircraft are provided and are stowed in the nose cone of the pod when not in use.

A fuel tank is provided within the pod enclosure and may be gravity filled when the supply drops to one-fourth of the tank capacity. Control of the unit is provided by a control panel on the pod. Aircraft engine starting air is controlled automatically from the aircraft through a remote control cable. (See fig. 4-18.) The RCPP-105 is intended for ground operation

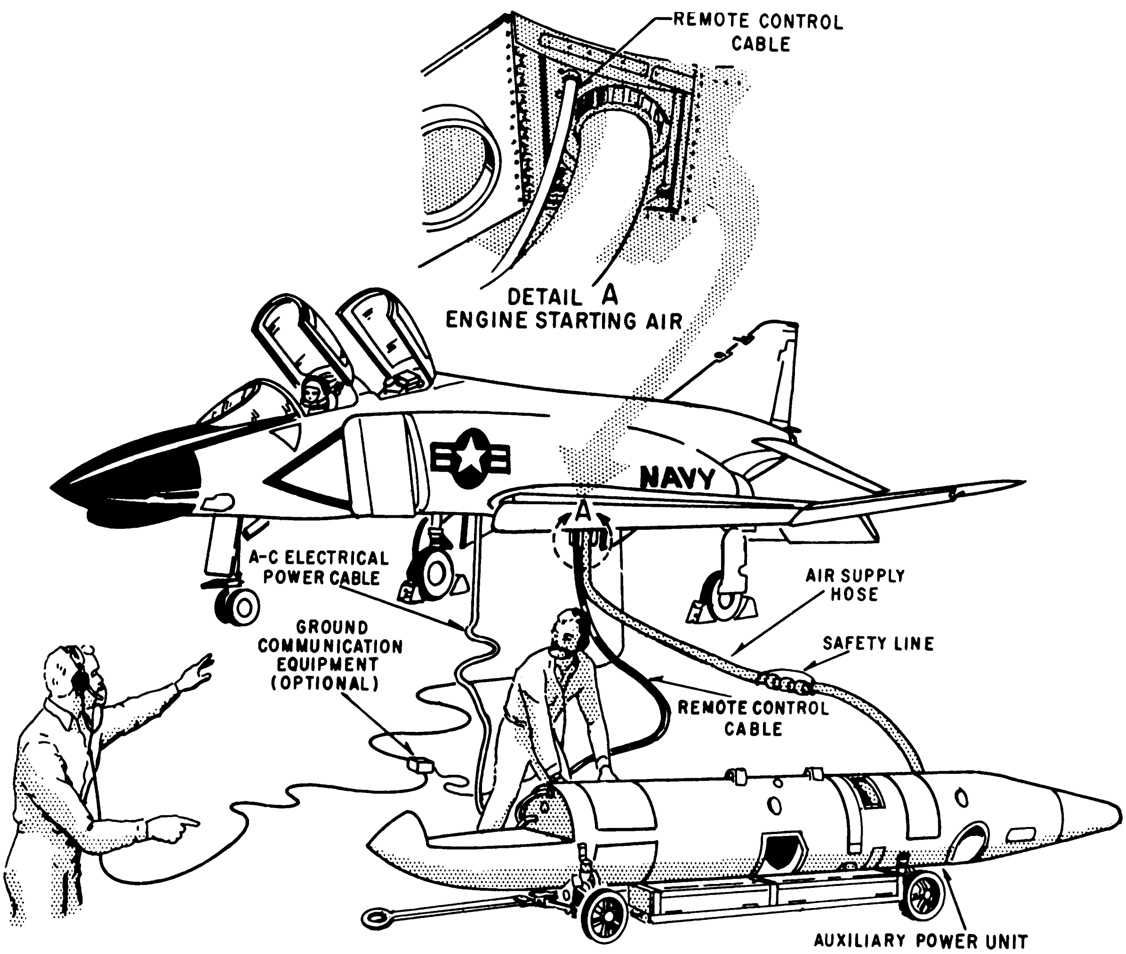

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Figure 4-18.—Starting aircraft engine with RCPP-105 gas turbine compressor.

only. It may be used at altitudes ranging from sea level to 10,000 feet. It is air transportable when inoperative.

Only qualified operators should attempt to operate this type equipment. Before moving the unit the securing straps should be inspected to insure that they are tight and in good condition. When moving the type pod which uses detachable wheels, the wheels should be checked for security. The pod should be moved slowly and carefully.

Tractor-mounted gas turbine units tend to be top-heavy. When driving this type vehicle, the speed limits should be strictly observed. Always turn corners slowly to prevent the possibility of overturning the vehicle.

Gas turbine power equipment may be damaged by trash, tools, or other foreign objects which may be left near the inlet duct. The trailer bed should be kept free of papers, bags, rags, and other debris.

When the unit is operating, the following precautions should be adhered to:

1. Stand clear of the inlet. Like aircraft jet engines, these units take in large quantities of air.
2. Stand clear of the exhaust and position the unit so that the exhaust does not strike the aircraft.
3. Stand clear of the plane of rotation of the turbine compressor. This area is generally clearly defined and marked on the equipment.
4. Do not connect or disconnect the ducting while the unit is operating.
5. Do not connect or disconnect the electrical cables while the switches are on.
6. Always stow the cables and ducting when not in use.

TRAILERS, DOLLIES, AND CARTS

This category includes equipment such as engine removal and transportation trailers, bomb trucks, oxygen and nitrogen servicing trailers, crash dollies, wheel removal dollies, preservation carts, load banks, weighing scales, water-alcohol trailers, weapon skids, shipment stands, and engine test stands. Several types of this category are described in the following paragraphs.

NOTE: Personnel of the AME rating are responsible for the maintenance of oxygen and nitrogen servicing equipment. Since these servicing units are usually mounted on trailers, the ASH may be required to perform maintenance and repair of structural members, tires, wheels, brakes, etc. on this equipment. The trailers for this type equipment are similar to other trailers used for support equipment; therefore, examples of oxygen and nitrogen servicing equipment are not presented in this section. However, safety precautions to be observed around oxygen and nitrogen and precautions to prevent contamination of oxygen and nitrogen systems are presented later in this chapter.

PRESERVATION/DEPRESERVATION TRAILER

Aircraft and aircraft components, as well as support equipment, must be preserved before shipment, storage, or extended repair periods. (See chapter 17.) The preservation must be removed before operating the aircraft or equipment. A preservation/depreservation trailer or cart is used for this purpose. One such unit is illustrated in figure 4-19.

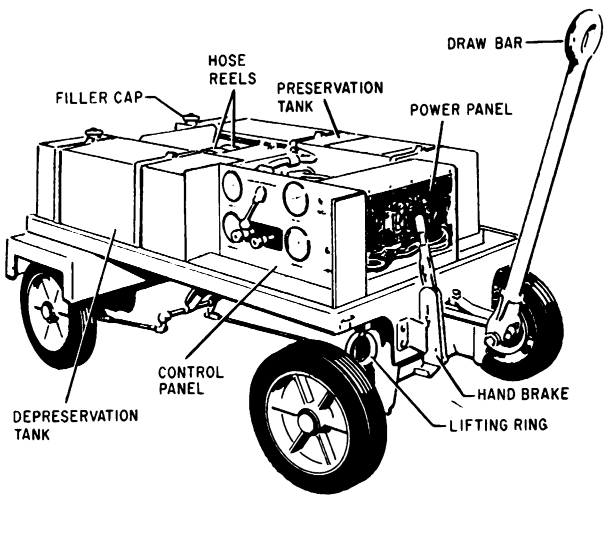

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Figure 4-19.—Preservation/depreservation trailer.

The chassis of this unit is of welded steel construction and so arranged as to be transportable by ship, cargo aircraft, and helicopters. Four-wheel suspension is provided with knuckle type steering of the front wheels to provide maneuverability. Internal expanding brakes are used to hold the trailer in position

when in use. A tow bar is provided with a lunette eye to permit towing by other vehicles. The enclosure is constructed to provide a non-skid working platform for maintenance personnel when servicing aircraft engines. All doors and panels are constructed to provide a weather tight seal and are arranged so that the internal components are readily accessible by personnel for operation, adjustment, or maintenance.

Two oil tanks are provided. An L-shaped depreservation tank with a 20-gallon working capacity is mounted on the right side of the trailer, and a rectangular shaped preservation tank with a 30-gallon working capacity is mounted on the left side. Both tanks are provided with cleanout openings, drains, and filler necks.

This unit is equipped with an electrically driven pump. The pump is capable of delivering either preservation or depreservation fluids at the rate of 3 gallons per minute against a head pressure from 0 to 250 psi. A 3-phase, 3-wire, 220/440-volt, 60-hertz electrical system is provided to operate the pump motor and strip heaters and their controls. The system is so wired that it may be easily connected for operation at either voltage. The system is connected to the external power supply by means of a 3-conductor cable 35 feet long and terminating in a standard 3-prong male plug. The heaters are arranged so that they may be operated at either 220 or 440 volts. They are capable of heating the oil reservoirs from 32° to 250°F within 1 hour.

CRASH DOLLIES

An aircraft crash dolly is illustrated in figure 4-20. These items are provided on all aircraft carriers for the moving of heavy aircraft components and to serve as aids in moving crashed aircraft. This is a heavy-duty, low-bed dolly of welded steel construction with a hard fiber top surface and four swivel shock absorbing caster type wheels with nonsparking tread. Pipe rails on all four sides of the dolly provide handholds and attachments for tiedowns.

These dollies can be modified in many different ways to serve specific purposes. One modification may be a steel structure to form a higher platform for use under a wing or nose section of the aircraft. Also, a heavy steel socket, large enough to insert a landing gear struct with the wheel broken off, is sometimes welded to the top of the dolly. Any modification

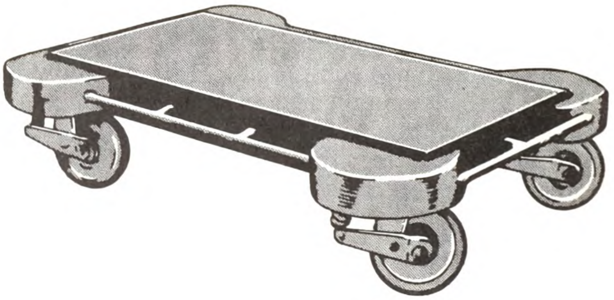

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Figure 4-20.—Aircraft crash dolly.

to the dolly must be sufficiently strong to safely handle the load that will be imposed upon it. As in the use of mobile cranes, these dollies are often used to support only a portion of the aircraft's weight. Other dollies are similarly used.

MISCELLANEOUS SUPPORT EQUIPMENT

Miscellaneous support equipment includes equipment such as jacks, workstands, hoists, tow bars, hoisting slings, ladders, wheel chocks, etc. Since these items contain mainly structural components and are usually operated mechanically or hydraulically, the ASH is primarily responsible for the maintenance of this category of support equipment.

JACKS

Tripod jacks are used when a complete aircraft is to be lifted. They are constructed of steel tubing and bars with a hydraulic cylinder in the middle. Each leg has a pad where the jack rests when being used and a retractable wheel that is used to move the jack. The hand operated hydraulic pump is located in the bottom of the cylinder. A threaded extension is provided to permit the jack to be used on different aircraft.

A single base jack is used when only part of the aircraft is to be lifted, such as lifting one wheel of an aircraft. This type jack is also used in the same manner for support equipment. Some of these uses are discussed in chapter 11. Jack hydraulic systems are described in chapter 14.

WORKSTANDS

There are many types of workstands required to perform maintenance on the various models of aircraft. Some are the fixed type, while others are adjustable.

The B-4A adjustable maintenance platform (fig. 4-21) is a hydraulically operated platform and ladder assembly mounted on a caster equipped base. This stand enables personnel to work in safety at heights varying from a minimum of 3 feet to a maximum of 7 feet. All four wheels have locks to make the platform stationary. Other workstands are often fabricated locally to permit repair of one certain type of aircraft. The hydraulic system of a typical workstand is discussed in chapter 14.

TOW BARS

There are two classes of tow bars, those designated as universal and those designated as special. The special tow bars are those designed for use with only one type of aircraft. The Aircraft Universal Tow Bar, NT-4, is designed to tow and position all carrier based aircraft. Attachment is dependent on the aircraft being towed and is accomplished by either axle pins or by hooks. (See fig. 4-22.)

For aircraft that have 3/4-inch holes provided for towing, the tow bar axle pins are installed in the tow bar with their small tapered end inboard. (The axle pins are held in the tow bar by quick-release pins. These pins can be removed by pressing the button in the handle and withdrawing the pin.) Engage the tapered pins in the towing holes of the aircraft. With the chain through the movable rail, engage the chain in the slot and tighten the chain by turning the knob (handtight) on the fixed rail.

Special tow bars are those designed by the aircraft manufacturer for a special purpose, or to tow an aircraft that has special handling characteristics.

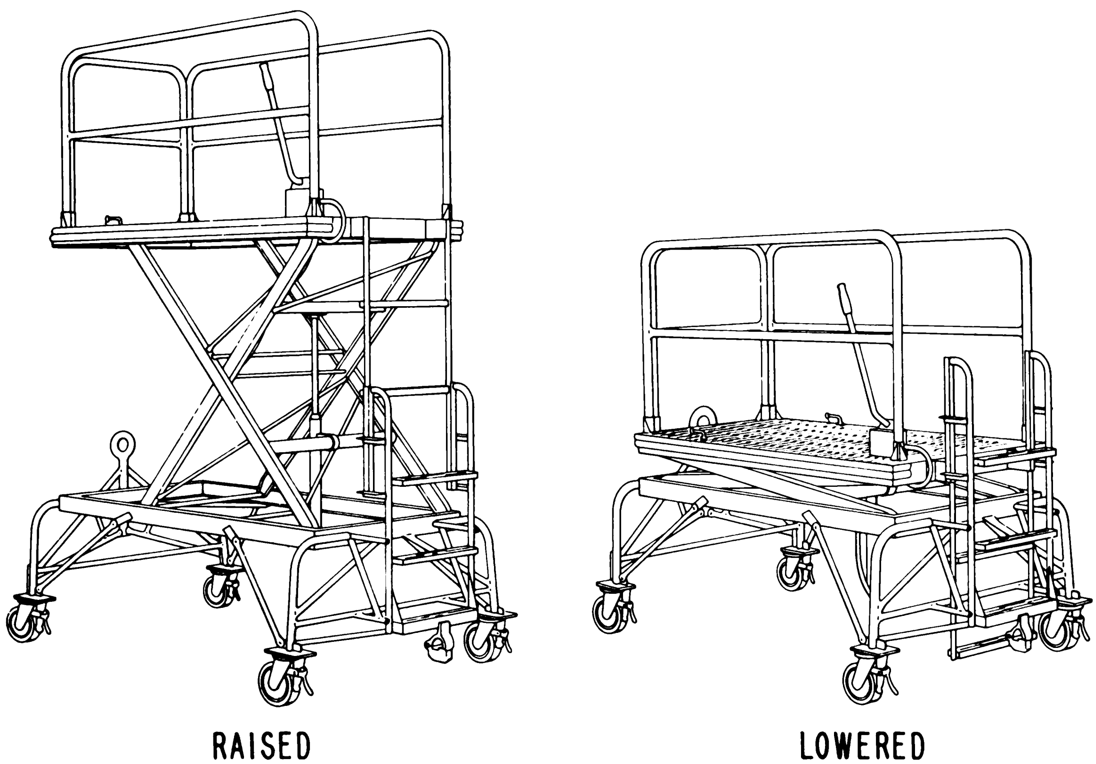

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Figure 4-21.—Adjustable maintenance platform.

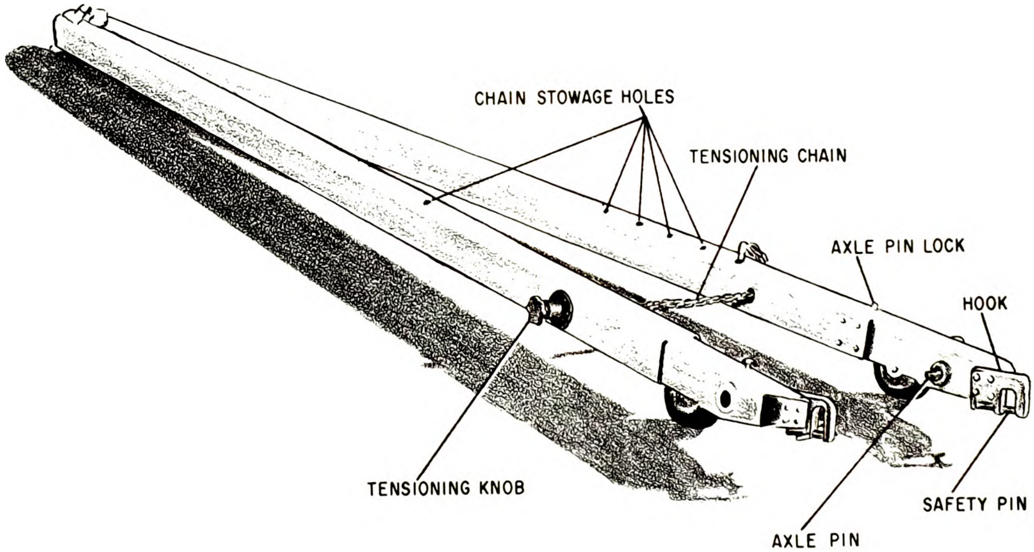

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Figure 4-22.—NT-4 Aircraft Universal Tow Bar.

CHOCKS

The universal chock used by the Navy is the Model MWC-2 Universal Wheel Chock. (See fig. 4-23.) This is an all-metal chock that is adjustable to fit any main landing gear wheel up to 45 inches in diameter.

Special chocks are made and used where standard or universal chocks are of insufficient size. At times, it may be necessary to make chocks for use where there are insufficient standard chocks for the number of aircraft aboard. These chocks can be made from many different materials; for example, wood and line, all wood, or metal tubing and chain.

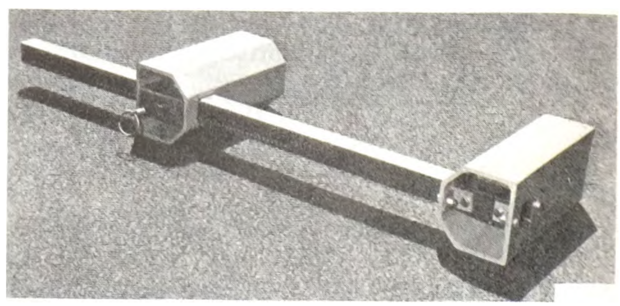

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Figure 4-23.—Universal wheel chock.

SERVICING GROUND SUPPORT EQUIPMENT

The proper servicing of ground support equipment is an extremely important part of maintenance. Most of the service requirements are simple, but nonetheless important. Servicing of support equipment includes the replenishment of fuels, lubricants, coolants, hydraulic fluids, and other consumable materials. All maintenance personnel should be familiar with the various types of servicing materials and their specific use. Proper selection of these materials is very important.

Some of the fuels, lubricants, hydraulic fluids, and coolants used in ground support equipment are discussed in the following paragraphs. Examples of servicing materials used in tow tractors are presented later in this chapter.

FUELS

Fuels for gasoline, diesel, and turbine engines are byproducts of petroleum. Petroleum products include gasoline, kerosene, diesel fuel, lubricating oils, gear lubricants, and greases. Many different additives are added to these byproducts to obtain a fuel that will perform efficiently in modern equipment.

Fuels must be handled with great care. They may be contaminated with dirt, rust, water, or by accidental combination with other types of petroleum products. Avoiding such contamination is vital if the products are to serve the purposes for which they are intended. Dirt and water in fuels are primary causes of premature engine failures. Cleanliness in handling fuels cannot be overemphasized.

The applicable Operating and Service Instructions lists the recommended fuel for the specific models of support equipment. Gasoline, diesel fuel, and jet propulsion fuels are the common fuels used in support equipment.

Gasoline

Gasoline is the most common fuel used in support equipment. The recommended gasoline for specific models of equipment is usually designated by octane rating. For example, the recommended gasoline for the NR-3A air-conditioning unit is 80 to 115/145 octane. Frequently, the specification of the recommended gasoline is also designated. The specification of the gasoline for the NR-3A is MIL-F-5572.

If all the potential heat energy contained in a gallon of gasoline could be converted into work, a motor vehicle could run hundreds of miles on each gallon. However, only a small percentage of this heat energy is converted into power by the engine. Most authorities consider the power losses within the engine to be as follows:

Engine	Percent of Power Loss
Cooling system	35
Exhaust gases	35
Engine friction	5 to 10
Total	75 to 80

The question of what is ideal gasoline is more theoretical than practical. Every manufacturer recommends the octane rating of the gasoline he feels is best for the engine he produces. Besides engine design, factors like the weight of the vehicle, the terrain and surfaces over which it is to be driven, and the climate and altitude of the locality also determine what gasoline is best to use. All other factors being equal, these may be considered as some of the properties of the best gasoline: good antiknock quality, a minimum content of foreign matter, and a volatility which makes starting easy and allows smooth acceleration and economical operation.

The type gasoline recommended by the manufacturer should always be used to get the maximum performance.

Gasoline contains carbon and hydrogen in such proportions that it burns freely and liberates heat energy. It evaporates at ordinary temperatures. Because gasoline vapors are heavier than air, they sink to the ground. To decrease the fire hazard of having the gasoline vapors in a confined space where spontaneous combustion could take place, the enclosure in which gasoline is used SHOULD BE THOROUGHLY VENTILATED THROUGH OPENINGS NEAR THE FLOOR.

The following safety precautions must be adhered to during fueling operations. These apply to all types of fuels. In addition, the Department of the Navy Safety Precautions for Shore Activities, NAVMAT P-5100, should be consulted for the safe handling of all fuels and other petroleum products.

1. No fueling shall be done within a closed building.
2. During fueling the operator and other personnel in the vicinity shall not smoke or light a match or lighter for any reason and there shall be no open flame in the vicinity.
3. Operators shall turn off engine and vehicle lights while taking on fuel.

Diesel

Diesel fuels are heavier than gasoline because they are obtained after gasoline and kerosene have been refined from the crude oil. The high-speed diesel engines used in ground support equipment require a fuel almost as light as kerosene. This diesel fuel has a specification as exacting as does gasoline. The recommended specification of diesel fuel is usually given in the appropriate Operating and Service Instructions.

Cleanliness is probably the most important and necessary property of a diesel fuel. The fuel should not contain any foreign substances because fuel pump and injector malfunction will result. Diesel fuel will hold dirt in suspension for longer periods of time than gasoline because it has a higher viscosity. Because of this, every precaution must be taken to keep dirt out of the fuel system or eliminate it before it reaches the pumps.

Water is more objectionable in diesel fuel than in gasoline because it causes ragged performance and will corrode the fuel system. The least amount of corrosion on the highly machined surfaces of the injection system equipment will cause it to become inoperative.

Jet Propulsion Fuels (JP)

Primarily, jet propulsion fuels (JP) are used in jet aircraft engines. However, the gas turbine power equipment requires JP fuels and some types of support equipment are equipped with multifuel engines designed to use several different types of fuel, including JP.

The jet fuels in use today are JP-4 and JP-5. JP-4 is widely used on shore stations for general use. JP-5 is a kerosene type fuel for use aboard ship. It has a higher flashpoint than JP-4. The applicable Operation and Service Instructions usually list the recommended JP fuel. Frequently either JP-4 or JP-5 is recommended.

Propane and Butane

Propane and butane fuels are byproducts of natural gas. (The natural gas is taken from a cavity in the earth.) Propane and butane fuels must be stored under pressure because they change to a gas when released in the atmosphere. Liquid propane becomes a gas at a temperature of -43°F; liquid butane, at 33°F. Although seldom used as a fuel for automotive equipment, small amounts of these products have been used to start engines in very cold climates. Some manufacturers believe that internal combustion engines can operate more economically with butane than with gasoline. Gasoline and diesel fuel, however, continue to be the most efficient fuels for internal combustion engines.

LUBRICANTS

The primary purpose of any lubricant is to reduce friction and eliminate metal-to-metal contact during operation of the equipment. Lubricant provides a film which permits surfaces to slide over each other with less friction. Therefore, lubrication is essential to prevent wear in any mechanical device where there are surfaces rubbing against each other.

Oils

In internal combustion engines, lubricating oils must perform four basic functions—lubrication, cooling, cleaning, and sealing. In order to properly lubricate the engine parts, the oil must be of low enough viscosity to flow readily between closely fitted parts that move rapidly but of high enough viscosity to prevent metal-to-metal contact between the parts. It must have a low enough pour point (lowest temperature at which it can be poured) to lubricate during starting at very low temperatures. The flashpoint of oil is the temperature at which it first gives off sufficient flammable vapor to ignite; this temperature ranges from 275° to 700°F. The fire point is the temperature at which the vapor will continue to burn and is usually 50° to 70° higher than the flashpoint. Lubricating oils must have high enough flash and fire point so that it will not burn, vaporize, or be consumed under high heat and be tough enough so that it will not break down or fail under high temperatures or pressures. The oxygen absorption of the oil must be low enough that varnish and gum do not form, and the oil must have small enough acid content not to be detrimental to engine parts.

Lubricating oil must cool moving parts by carrying off waste heat. This is especially true in diesel engines. Diesel engines generate so much heat that an oil cooler is used to transfer the heat from the oil to another medium. In order to perform its cooling function, lubricating oil must be able to flow readily.

Another major function of lubricating oils is cleaning. This means carrying dirt, small carbon and metal products, gum, and varnish from the engine parts. Filters have been developed to remove part of the dirt, and ventilation systems have been designed to carry off vapors and moisture. However, these devices perform only part of the job. Therefore, additives or detergents are blended with lubricating

oils. The detergent is soluble in the oil and cleans the dirt, gum, and other impurities from the engine and holds them in suspension. These suspended impurities are removed by the filter; therefore, the oil and the filter must be changed at regular intervals. If the oil is not changed, the amount of gum and varnish increases to the point where the oil can no longer hold them in suspension and these substances are deposited throughout the engine.

Another function of lubricating oil is to seal the space between the piston rings, cylinder walls, and pistons to prevent leakage of combustion gases from the combustion chamber, past the rings, into the crankcase. When this space is properly sealed by the lubricating oil, the full force of the combustion is expended on the head of the piston and none of the force is lost.

The military specification for lubricating oils for ground support equipment prescribes that the oil be a petroleum or synthetically prepared product or a combination thereof. This oil is intended for the lubrication of internal combustion engines and for general purpose lubrication. This oil is of three viscosity grades—SAE10, SAE30, and SAE50. The SAE stands for the Society of Automotive Engineers who have established an arbitrary system for classifying motor oils according to their viscosities.

In addition to the engine, other parts of ground support equipment require lubricating oils. These include the transmission, differential, and steering gear unit. Standard transmissions normally require SAE80 or SAE90 grade oil. In some cases these oils are recommended for use in differentials and steering gear units. However, the manufacturer's recommended grade oil should always be used in all parts and components.

The oil used in automatic transmissions more closely resembles hydraulic fluid than lubricating oil. However, only automatic transmission oil should be used in automatic transmissions. This oil has been specially prepared for use in modern day automatic transmissions. For example, the transmission of the MD-3 tow tractor requires Automatic Transmission Fluid, Type "A" and the MB-5 Fire Truck requires MIL-L-2104B.

Greases

Grease is used where oil cannot perform the desired lubrication. On ground support equipment, grease is used in wheel bearings, for chassis lubrication, and such other places that the manufacturer stipulates. The most important requirements of greases are stability, noncorrosiveness, water resistance, and satisfactory performance in operation. A grease must be stable both in storage and in use. It must be free from bleeding (separation of oil), oxidation, and changes in consistency. The grease must not chemically attack the metals and other materials with which it comes in contact. A grease which is insoluble in water is required in some cases, while in others the grease must resist weathering or washing action of water.

Various soaps are used in the manufacture of grease. These soaps regulate the water resistance and the heat stability of the grease.

The various greases required for the lubrication of support equipment are designated by specification numbers. Always use the specification and grade of grease recommended by the manufacturer.

HYDRAULIC FLUIDS

Hydraulic fluid is the means of transmitting energy from the pump to the various units to be actuated. In order to operate efficiently in the system, hydraulic fluid must have certain properties and characteristics. It must have the ability to flow freely at extremely low temperatures, as well as high temperatures. It must be noncorrosive to metals and must not react chemically on the packings and seals used in the system. Hydraulic fluid must also have good lubricating qualities, and it is desirable that it be nonflammable.

Several different types of hydraulic fluids are used in support equipment. The manufacturer recommends the specification to be used. For example, the hydraulic system of the MD-3 tow tractor utilizes Automatic Transmission Fluid, Type "A." Most brake systems use a nonpetroleum hydraulic brake fluid such as Specification VV-H-910 or VV-B-680. However, the most common fluid used in hydraulic systems of ground support equipment is Specification MIL-H-5606B. This is the same type of fluid that is used in aircraft hydraulic systems. This fluid is colored red and is available in metal containers of 1 quart, 5 gallons, and 55 gallons, and in 16-ounce spray cans. Hydraulic test benches for testing hydraulic components utilize preservation hydraulic fluid,

Specification MIL-H-6083C. A description of this type fluid is presented in chapter 17.

A majority of malfunctions of hydraulic systems and components are attributed to contamination of hydraulic fluid. Due to close tolerances existing between the operating parts of hydraulic components, it is important that extreme cleanliness precautions be taken when servicing and maintaining hydraulic systems. The cleanliness of hydraulic fluid in any hydraulic system is very important. It is of extreme importance that all aircraft hydraulic support equipment, such as hydraulic test stands, be maintained in a satisfactory state of cleanliness. Chapter 14 of this manual contains a section devoted entirely to hydraulic fluid contamination control.

COOLANTS

Nearly all engines used in automotive ground support equipment use a liquid cooling system. Any liquid used in this type of cooling system is called a coolant. The two types of coolants—water and antifreeze solutions—are discussed briefly.

Water used in cooling systems should be clean and must be checked frequently.

A vehicle operated in temperatures below 32°F requires an antifreeze solution in its cooling system. Without this solution, the water in the cooling system freezes and this sometimes results in a cracked cylinder, water jacket, cylinder head, and/or radiator core.

A good antifreeze mixes readily with water. Once it is mixed with water, it tends to penetrate openings and connections more readily than water. Upon the first filling of antifreeze in the winter, and periodically thereafter, hose connections should be checked for tightness to insure that there are no leaks. A good antifreeze is not subject to rapid evaporation, nor does it corrode or rust the cooling system. Most antifreeze compounds contain a rust and corrosion inhibitor. Without an inhibitor in the solution, rust and corrosion will clog the radiator and cause the engine to overheat.

All antifreeze solutions require periodic checks and must be renewed when tests show that they will not give the required protection against freezing. Hydrometers are used for testing antifreeze solutions.

Antifreeze solutions, even the so-called permanent types, are not recommended for use beyond one season; furthermore, it is recommended that different types not be mixed. Usually when one type has been mixed with another there is no way of knowing the temperature at which the mixed solutions will freeze. Another danger is that their ingredients sometimes react chemically and cause corrosion in the cooling system and a foaming that forces quantities of the liquid from the radiator.

SERVICING PROCEDURES

Servicing of ground support equipment is not usually a complicated task; however, it is extremely important. As indicated by the foregoing discussion, there are many different types of materials used in the various types of equipment. One item of equipment may require several different types of oil, grease, fluids, etc. Selecting the correct type and proper application can mean the difference between an item of equipment providing excellent performance or one that is damaged beyond repair.

Timely checking the different systems for replenishment needs is an important part of servicing. Quantity gages are normally provided for fuel. However, other means must be used to check such items as engine oil, hydraulic fluid, power steering fluid, transmission fluid, coolants, tire pressures, etc. To insure that checks for replenishments are timely, they are usually included in the scheduled maintenance inspections of the equipment.

Complete servicing details can be found in the Operation, Service, and Repair Instructions for the specific item of equipment. Figure 4-24 and table 4-2 illustrate a small portion of the servicing information contained in the Service Instructions for the MD-3 tow tractor. The intervals for changing these consumable materials and for lubricating various points are also included.

Many types of support equipment are provided with Maintenance Requirements Cards which are utilized for conducting periodic inspections. These cards, which are discussed later in this chapter, also contain servicing information and should be used in conjunction with the applicable Service Instructions Manual.

INSPECTIONS

All items of ground support equipment are required to be inspected periodically. The frequency and intensity of these inspections vary with the complexity of the equipment.

For example, aircraft tow bars require only visual inspections for the security of attachment fittings, structural condition, and evidence of corrosion. In contrast, such items as tractors, weapons loaders, gas turbine compressors, etc., require a more systematic method of inspection. This is only because of the complexity of the equipment and does not in any way imply that inspection of some equipment is more important than others.

Many items of support equipment are subject to a variety of stresses, strains, vibrations, and detrimental environments. If not inspected regularly for defects, the equipment would soon become inoperable. Maintenance, such as correcting discrepancies and timely lubrication, is performed in conjunction with inspections and enables the equipment to be safely used until the next inspection. It is the need for this type maintenance that has given rise to the Planned Maintenance System. This maintenance system pertains primarily to preventive maintenance (inspection and routine servicing) rather than to corrective maintenance.

The types of inspections performed by activities responsible for the maintenance of ground support equipment are as follows:

1. Acceptance Inspection. A minimum acceptance inspection consists of an inventory of installed material and loose gear, configuration verification, functional tests of systems, and a thorough preoperational inspection. Accepting activities may elect to increase the depth of inspection if the condition of the equipment warrants.

2. Preoperational Inspection. The preoperational inspection was formerly known as a daily inspection. On some of the older items of equipment, these inspections are still referred to as daily inspections. Preoperational inspections are accomplished prior to the first use of the subject equipment for that day. This inspection is basically a combination of requirements for checking equipment that requires verification of satisfactory functioning prior to use, plus requirements that prescribe searching for and correction of relatively minor problems to prevent their progress to a state that would require major work to remedy. When completed, the preoperational (daily) inspections are signed off on the Ground Support Equipment Daily Record attached to the equipment. An example of this card is illustrated later in this chapter.

If the equipment is used more than once during the day, a brief inspection should be performed prior to each use. This inspection need not be as detailed as the preoperational or daily inspection. The Ground Support Equipment Daily Record should be checked to insure that the preoperational or daily inspection has been completed. This should be a visual inspection for condition, fuel level, oil level, water level, etc., and for proper operation.

Special maintenance requirements that occur at intervals more frequent than prescribed for calendar inspections are also included on the day they become due, if practicable. (See Special Inspections, described later.)

3. Postoperational Inspection. As applied to support equipment, this is not a formal inspection. However, it is a very good practice to conduct postoperational inspections. This inspection includes an operational check before securing (stopping) the equipment and a visual inspection for condition, fuel level, oil level, water level, etc., after the equipment is stopped. As a result of this inspection, the equipment will be ready for the next use. Protective devices, such as panels, covers, etc., should be replaced when the equipment is not in use.

4. Calendar Inspection. The calendar inspection was formerly known as a periodic inspection. On some older types of support equipment, these inspections are still referred to as periodic inspections.

Calendar inspections are limited overall examinations of a specific item of equipment. The interval between inspections depends upon the type of equipment. The intervals may be in terms of days, weeks, months, hours, starts, etc., or some combination of these.

5. Special Inspections. A special inspection is an inspection that depends upon occurrence of certain circumstances or conditions, or a maintenance action with a prescribed interval occurring more frequently than periodic inspections. Inspections required at intervals, such as 10 hours, 30 hours, 7 days, etc., are usually classified as special inspections. These inspections are accomplished along with the preoperational inspection as they come due.

Scheduled maintenance inspections for ground support equipment are promulgated by the Naval Air Systems Command. With every activity using the inspection criteria prescribed for their assigned equipment, it follows that any given equipment model is subject to a standardized program of periodic maintenance

Table 4-2.—Lubrication and refill chart, MD-3 tow tractor.

ITEM	Lube Symbol	TYPE REFILL AND SERVICE			Approximate Refill Capacity	OPERATION (Hrs Oper.)		
		SAE	API	Military Specification		Check	Clean	Refill or Replace
Engine Crankcase With Filter Above -32° F -32°F to -10°F Below -10° F	EO	 30 (20) 10W	DM-DS	MIL-L-2104, Amd. 1 or MIL-L-9000E	9 qt	10	1000	200
Air Cleaner	EO	Same As Engine			1 pt	10	100	100
Engine Breather	EO	Same As Engine			*AR	200	200	200
Transmission	Automatic Transmission Fluid, Type "A"				13 qt	10	500	1000
Hydraulic System					5 pt	10	500	1000
Air Compressor Above -32° F -32°F to -10°F Below -10° F	EO	 30 (20) 10W	MS-DG	MIL-L-2104, Amd 1 or MIL-L-900E	*AR	10	1000	200
Rear Axle Differential Below 32° F Above 32° F	GO	 90 140	EP	MIL-L-2105	4 pt	200	1000	1000
Wheel Hubs Below 32° F Above 32° F	GO	 90 140			2.75 pt (Per Hub)	200	1000	1000
Cooling System Above 32° F Below 32° F	Water and 5% Corrosion Inhibitor Solution Ethylene Glycol			 O-A-548	22 qt	10	1000	1000
Brake Fluid	HB	Non-Petroleum Base		VV-H-910	*AR	100	1000	1000
Fuel System		JP-5		MIL-J-5624	90 gal	10	1000	10
Front Wheel Hubs	GAA	Multi-Purpose Lithium Base NLGI Grade 1		MIL-G-10924	*AR	200	1000	1000
Drag Link					*AR	100	500	100
Tie Rod					*AR	100	500	100
King Pins					*AR	100	500	100
Accelerator Pivots					*AR	100	500	100
Drive Shaft					*AR	100	500	500
Brake Lever					*AR	200	200	200
Batteries	Distilled Water				*AR	100	200	100
Turbine Oil				MIL-L-7808, Grade 10				

*AR - As Required

NOTE: Base oils used to obtain SAE 20, 10W/30 and 40 viscosity weights should meet the requirements of MIL-L-2104.

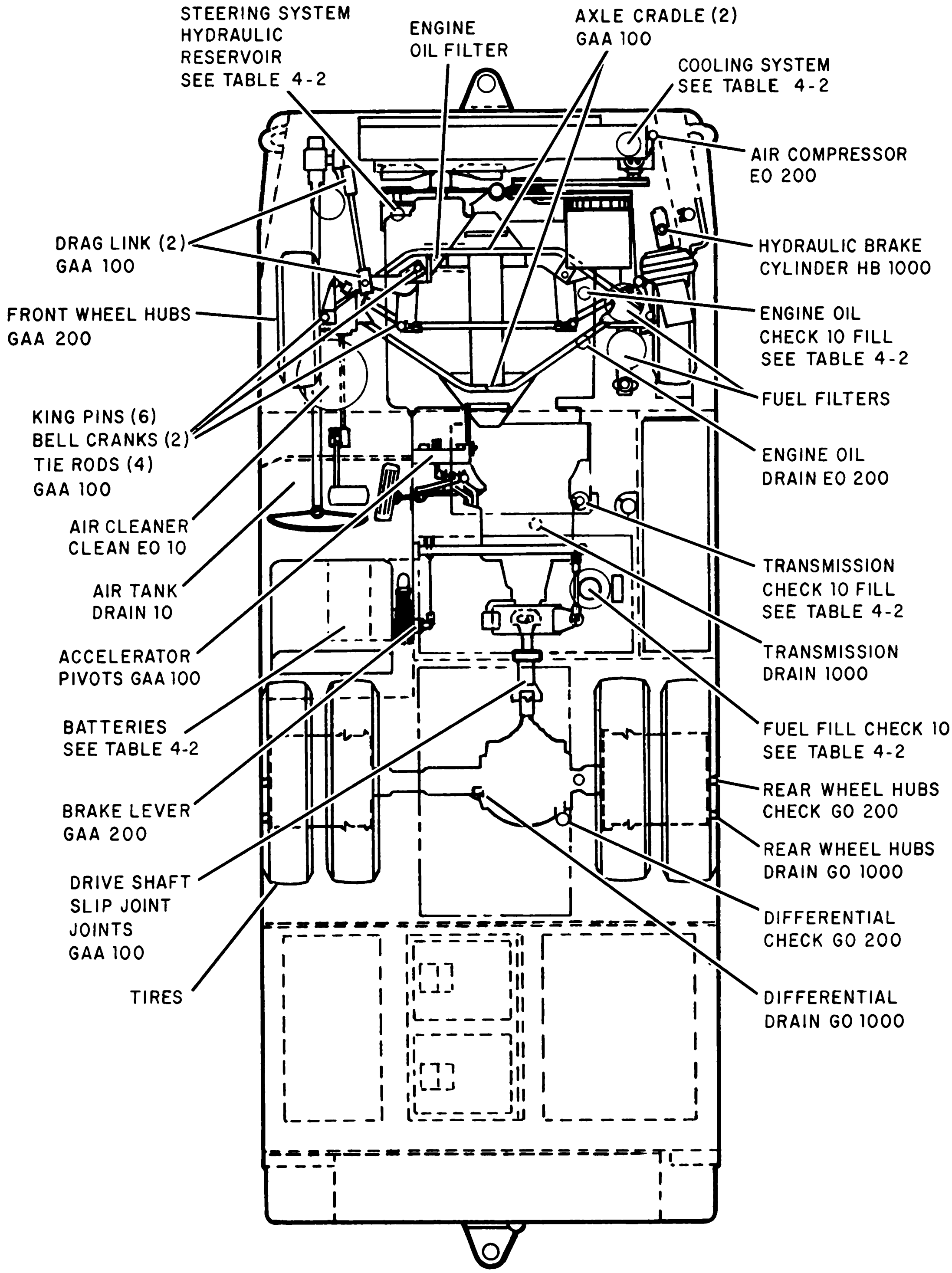

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Figure 4-24.—Lubrication diagram, MD-3 tow tractor.

wherever it is being operated. These inspections provide the minimum requirements necessary to maintain the subject equipment. Inspections to a greater depth and at an increased frequency may be required by local conditions.

Standardization of periodic maintenance procedures is accomplished by the use of applicable Service Instructions, Maintenance Requirements Cards (MRC's), or a combination thereof.

SERVICE INSTRUCTIONS

As stated in chapter 2, the Service Instructions are a part of the Operation and Service Instructions Manual, which is often combined with other instructions and the parts breakdown. The Service Instructions contain the planned periodic maintenance requirements for the applicable item of equipment. The maintenance requirements contained in the manual are set forth in a manner to specify the items to be inspected or examined and the conditions to be sought in each case.

The Service Instructions contain only minor maintenance procedures, such as servicing, minor adjustments, and lubrication charts. A list of the required special tools is also provided. The applicable troubleshooting charts, Repair Instructions, or Overhaul Instructions must be consulted for the correction of major discrepancies found during periodic inspections.

In some Service Instructions, the scheduled inspections are itemized in paragraph form. However, most of the later publications present these inspections in table form. The format of these tables varies in different Service Instructions. A portion of a typical table is illustrated in table 4-3.

MAINTENANCE REQUIREMENTS CARDS (MRC's)

Many types of support equipment are under the Planned Maintenance System. Under this system, each type of support equipment is provided with Maintenance Requirements Cards (MRC's). These cards provide the minimum requirements necessary to maintain the subject equipment in a satisfactory and effective operational readiness condition. These are 5 x 8 cards arranged by rating and work area to provide the most efficient sequence of accomplishment. Assembled into sets and numbered in sequence, the cards contain pertinent information required by each maintenance man to complete each task.

NOTE: Military Requirements for Petty Officer 3 & 2, NavPers 10056 (Series), should be consulted for a description of the Planned Maintenance System and for the explanation of the information contained in each block and column of the cards.

As applied to ground support equipment, individual sets of MRC's are prepared for preoperational (daily) and calendar (periodic) inspections. Preoperational Maintenance Requirements Cards list those requirements necessary to be performed by the using activity. Calendar Maintenance Requirements Cards list the responsibilities of the activity having prime custody of the equipment.

MRC sets are identified by the publication number system for manual publications described in chapter 2. NW 17-600-12-6-1 and NA 19-600-24-6-4 are examples of publication numbers identifying MRC sets for ground support equipment. The prefix NA indicates that the cards are published by the Naval Air Systems Command. NW indicates that the cards were published by the old Bureau of Naval Weapons. As the NW cards are revised, the prefix will be changed to NA. The numbers 17 and 19 are the general subject classification numbers assigned to ground support equipment. (See chapter 2.) The number 600 identifies the publication number as MRC's.

The next number (-12 and -24 in the two examples) identifies each set of MRC's with a specific item of equipment. This number is sequential for each of the 17 and 19 series and is assigned as the cards are developed.

The numbers -6-1 are assigned to Preoperational MRC's and the numbers -6-4 to the Calendar MRC's.

NOTE: Card sets presently in the system numbered NA 17 or 19-600-___-6 (Daily) and NA 17 or 19-___-7 (Periodic) will retain these identifying numbers until superseded by a new publication or the equipment is phased out and the cards canceled.

The MRC's which are available for ground support equipment are listed by publication number and title in the Navy Stock List of Forms and Publications, NavSup Publication 2002, Section VIII, Part C, and its supplements. The ordering procedure is the same as that for manual publications, described in chapter 2.

Table 4-3.—Inspection procedures.

Component or location	Nature of inspection	Daily or 10 hours	Weekly or 50 hours	Monthly or 250 hours	Semiannual or 500 hours
Chassis.	Inspect for dirt and damage.		X		
	Inspect door and panel assemblies for proper cleaning and closing.	X			
	Inspect for damage, or corrosion.	X			
Wheels and tires.	Inspect for damage and proper inflation.	X			
	Check wheel nuts for tightness.		X		
	Inspect for evidence of leakage of wheel bearing lubrication.		X		
Hydraulic system.	Check hydraulic pump and motors for leaks and security of mounting.		X		
	Check hydraulic lines for damage and leaks.	X			
	Check hydraulic oil level and add oil if necessary.			X	
	Drain and refill hydraulic oil tank.				X
	Check all fittings and connections for tightness.			X	
	Check operation of hydraulic units and check for leaks.		X		
Gearcase.	Check oil level.	X			
	Check for oil leaks at lines, fittings, and gaskets.		X		
	Drain oil and refill.				X
Brakes.	Inspect brake lining for appearance and wear. Replace lining when worn 1/16 inch.	Annual			
	Adjust mechanical brakes by adjusting the parking brake cable at the brake handle.			X	

NOTE: No part of any scheduled maintenance is certified (signed off) on the Maintenance Requirements Cards; therefore, they may be used as many times as their condition permits.

An example of Preoperational Maintenance Requirements Cards is illustrated in figure 4-25. This complete preoperational inspection is contained on one card (front and back). Preoperational MRC's for some types of the more complex equipment require several cards in each set. An example of Calendar MRC's is illustrated in chapter 10. (See fig. 10-34.)

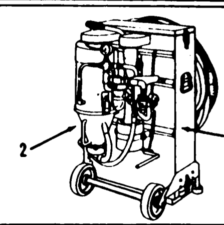
NAVAIR 17–600–22–6–1

PREOPERATIONAL MAINTENANCE REQUIREMENTS
PORTABLE DRY HONING MACHINE
(VACU–BLAST CO.)

PUBLISHED BY DIRECTION OF THE COMMANDER OF THE NAVAL AIR SYSTEMS COMMAND

WORK AREA

1. Cabinet Assembly
2. Hopper and Air Controls



WORK AREA		ELEC PWR N/A / HYD PWR N/A
1,2	1. Components and structural members for distortion and secure attachment.	
1	2. Abrasive feed and return hoses for soft spots and secure attachment.	
1	3. Blast gun for distortion; nozzle for excessive wear, 7/16 in. maximum.	
2	4. Hopper for adequate abrasive, 2-1/2 lb. minimum.	
1,2	5. Covers and latches for security.	

WORK AREA	NAVAIR 17-600-22-6-1 OPERATIONAL CHECK	ELEC PWR N/A / HYD PWR N/A
2	1. Relieve tension on pressure regulator diaphragm.	
	2. Connect service line to air source; 80 to 100 psi.	
	NOTE: Test surface must be free from water, oil and excessive debris.	
2	3. Adjust to desired pressure while in operation.	
	4. Move the blast gun over the surface 3 feet in 30 seconds: a. cleaned path must be uniform and at least 1 inch wide. b. abrasive must not escape to the atmosphere.	
	5. Release the blast control valve; the abrasive flow must reverse direction so as to completely purge the hose in 10 seconds.	
1,2	6. Secure unit and stow hoses.	

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Figure 4-25.—Sample Preoperational Maintenance Requirements Cards—portable dry honer.

MAINTENANCE AND CUSTODY RECORDS

To insure an accurate maintenance history of each item of ground support equipment for which Maintenance Requirements Cards are provided, three records are required to be maintained. These records are the Support Equipment Sub-Custody and Periodic Maintenance Record, the Support Equipment Custody and Maintenance Record, and the Ground Support Equipment Daily Record.

Sub-Custody and Periodic Maintenance Record

The Sub-Custody and Periodic Maintenance Record, OpNav Form 4790/50, illustrated in figure 4-26, is maintained on each applicable unit of support equipment by the supporting or using activity.

The front of the form is used to record basic item identification and sub-custody information. The back of the form is used to record operating and periodic maintenance information. It also contains instructions for use of the form. Entries are made on the periodic maintenance record by the activity having prime custody of the equipment and who loaned such equipment on a sub-custody basis.

For the most part, the column headings on this form are self-explanatory. On the subcustody record in the column titled Date Due for PM (periodic maintenance) is entered the date on which scheduled maintenance is due. The equipment is returned to the prime custodian for the accomplishment of periodic maintenance.

On the periodic maintenance record the columns titled Hours and Starts are used to record operating data. Some types of support equipment have hour meters to register operating time and some have start meters to register the number of starts since, in some cases, starts are more significant from a usage standpoint than actual running or operating time. Other types of support equipment have no provisions for registering operating time; therefore, the user of the equipment must keep account of daily usage.

NOMENCLATURE	MODEL/TYPE	SERIAL NO.	MANUFACTURER
Air Compressor	NHPC-2 515HGP4	669532	Joy

SUB-CUSTODY RECORD

DATE	ACTIVITY	CONDITION/REMARKS	DATE DUE FOR PM	DATE RETURNED	CONDITION/REMARKS
5/26/71	VA-65	EXCELLENT	7/8/71	7/8/71	Excellent
7/9/71	VA-95	EXCELLENT	8/19/71	7/31/71	Engine malfunction
8/3/71	VA-85	EXCELLENT	8/19/71		

GROUND SUPPORT EQUIPMENT SUB-CUSTODY AND PERIODIC MAINTENANCE RECORD
OPNAV FORM 4790/50 (12-69) *Use with OPNAV FORM 4790/51 (12-69)* S/N 0107-770-5300

OPNAV FORM 4790/50 (12-69) (BACK)

PERIODIC MAINTENANCE

HOURS	STARTS	REMARKS	DATE COMP.	ACTIVITY	SIGNATURE
100		SCHEDULED MAINTENANCE COMPLETED	7/8/71	AIMD NAS OCEANA	S. Pace
125		REPLACED MAGNETO	8/2/71	AIMD NAS OCEANO	G. L. Takken

Instructions for use of OPNAV Form 4790/50
Use with OPNAV Form 4790/51.
When either Periodic Maintenance or Sub-Custody Record sides are completed, transfer operating total times to a new OPNAV Form 4790/50 and discard old card.
NOTE: OPNAV Form 4790/51 and 4790/50 shall be completed as required and accompany equipment on transfer

OPERATING TIME RECAPITULATION	HOURS	STARTS
1 SINCE NEW *(Brought forward)*	0	
2 SINCE OVERHAUL *(Brought forward)*		
3 TOTAL USAGE - THIS CARD		
4 SINCE NEW *(1 + 3)*		
5 SINCE OVERHAUL *(2 + 3)*		

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Figure 4-26.—Support Equipment Sub-Custody and Periodic Maintenance Record.

Custody and Maintenance Record

The Custody and Maintenance Record, OpNav Form 4790/51, illustrated in figures 4-27 and 4-28, is maintained by the supporting or using activity accountable for and having prime custody of each unit of equipment. Entries on this form are made, as required, in order to provide a maintenance history. A record is maintained on each unit of support equipment until the unit is retired.

The front of this form is divided into four major sections. The first section is used to record acceptance information; the second provides for a custody and transfer record; the third is the rework record; and the fourth section is the preservation/depreservation record.

The back of this form is divided into two major sections. The first section is used to record replacement of major parts, and the second is used to record the incorporation of technical directives.

Daily Record

A Ground Support Equipment Daily Record, OpNav Form 4790/52, illustrated in figure 4-29, is maintained by the using activity for each item of support equipment. This form is kept with the equipment in a suitable container. Entries are made to reflect all preoperational (daily) maintenance performed. Additionally, this form is used to record all operating times for units not equipped with meters. Operating times are logged as hours/starts/miles, as appropriate.

These records are maintained on a monthly basis. At the beginning of each month or upon the completion of a card (if the completion is first), the activity having primary custody of the equipment issues a new card for each item of GSE. These new cards are exchanged for the old/completed cards. The old/completed cards are retained on file for 3 months, at which time they are destroyed if no longer needed.

The current Support Equipment Sub-Custody and Periodic Maintenance Form and the Support Equipment Custody and Maintenance Record accompany the equipment when transferred between activities on a permanent basis. All three forms are available through local supply activities as listed in NavSup Publication 2002, Section II.

GENERAL SAFETY AROUND SUPPORT EQUIPMENT

Safety around ground support equipment is largely a matter of commonsense. Commonsense dictates what measures should be taken to make working around ground support equipment as safe as possible. The full cooperation of all personnel working with and around support equipment is required, and constant vigilance must be maintained to eliminate unsafe acts.

General safety rules require that all personnel must strictly observe all safety precautions applicable to their work. Each worker concerned should report to his supervisor any unsafe condition, material, or equipment; warn others who appear to be endangered by hazards or by failure to observe safety precautions; and report any injury or evidence of impaired health that occurs to himself or to others.

Each worker should wear or use protective clothing or equipment prescribed for the safe performance of the work he is doing. When a hazardous condition occurs, each person should exercise as much caution as is possible under the existing circumstances.

Some of the safety measures that should be used around ground support equipment are covered in the following paragraphs.

When stopping self-propelled equipment, set the handbrake or chock the vehicle. This should be done to towed equipment before unhooking. When mobile equipment is handpushed or pulled, the brakes should be set or the wheels chocked as soon as the vehicle is stopped.

Aboard aircraft carriers, any ground support equipment that is not in use is tied down. This prevents a tight turn or any tilting of the ship from causing the equipment to become a hazard to personnel or other equipment. All equipment should be as clean as possible to prevent accumulation of fuel, oil, hydraulic fluid, or grease from becoming a fire hazard or causing slippage by those working with or on the equipment.

Each piece of ground support equipment should be used only for the purpose for which it was manufactured. Only qualified and authorized personnel should operate ground support equipment.

Specific safety precautions applicable to the hydraulic and structural maintenance of support equipment are presented in appropriate chapters throughout this training manual. As stated

ACCEPTANCE INFORMATION

NOMENCLATURE	MODEL/TYPE	SERIAL NUMBER	MANUFACTURER
Air Compressor	NHCP-2 515HGP4	669532	Joy

ACCEPTANCE DATE	ACCEPTING ACTIVITY	CONTRACT NO	DRY WEIGHT	REMARKS	SIGNATURE
5/24/71	NavFlantRepO Norfolk, Va	N600 (76) 55856	2020 lbs		D. Beck

CUSTODY AND TRANSFER RECORD

DATE	FROM	TO	AUTHORITY	REMARKS	RECEIVED
5/25/71	NAS SUPPLY NORFOLK, VA.	NAS OCEANA	NAVAIRSYSCOM LT 36474	RFI	P. Kimball

RECORD OF REWORK

DATE INDUCTED	DATE COMPLETED	DESCRIPTION OF WORK	AUTHORIZATION	ACTIVITY	SIGNATURE

PRESERVATION/DE-PRESERVATION RECORD

DATE PRESV	DUE DATE RE-PRESV	TYPE	DATE DE-PRESV	DIRECTIVE COMPLIED WITH	REASON FOR INACTIVE STATUS	PRESV/DE-PRESV. BY ACTIVITY	SIGNATURE

GROUND SUPPORT EQUIPMENT CUSTODY AND MAINTENANCE RECORD
OPNAV FORM 4790/51 Use with OPNAV Form 4790/50

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Figure 4-27.—Support Equipment Custody and Maintenance Record (front).

OPNAV FORM 4790/51 (BACK)

REPLACEMENT OF MAJOR PARTS RECORD

NOMENCLATURE	INSTALLATION DATA				REMOVAL DATA				JCN	ACTIVITY
	DATE	SERIAL NO	HOURS SINCE NEW	HOURS SINCE O H	DATE	SERIAL NO	HOURS SINCE NEW	HOURS SINCE O H		
MAGNETO-Y98ASZ	8/2/71	56432	0	0	8/2/71	56427	125	—	A9D0008489	AIMD, NAS OCEANA

TECHNICAL DIRECTIVES

NO.	STATUS	CAT.	DESCRIPTION	COMPLIANCE		SIGNATURE
				ACTIVITY	DATE	
SEC 1710	INC	R	INSTALLATION OF FOREIGN OBJECT DAMAGE CONTROL TIRES	AIMD, NAS OCEANA		

AS.679

Figure 4-28.—Support Equipment Custody and Maintenance Record (back).

NOMENCLATURE	MODEL/TYPE/EQUIP.	SERIAL NO.	MANUFACTURER	CONTRACT NO.
AIR COMPRESSOR	NHPC-2	669532	JOY	N600(76)55856

INSPECTION PERFORMED (Inspector)		CUMULATIVE USAGE (To be recorded by Supervisor)				
DATE	SIGNATURE	PRIMARY UNIT		SECONDARY UNIT		SIGNATURE
		HOURS/TENTHS	STARTS	HOURS/TENTHS	STARTS	
8/3/71	S.D. Baker	4				C.E. Jones
8/4/71	C.A. Thomas	7				C.E. Jones

GROUND SUPPORT EQUIPMENT - DAILY RECORD - OPNAV FORM 4790/52 (12-69)
S/N-0107-770-5500

AS.680

Figure 4-29.—Ground Support Equipment Daily Record.

previously, the ASH may be required to perform structural maintenance on oxygen and nitrogen servicing trailers. When working around this equipment it is extremely important that all safety precautions applicable to the handling of oxygen and nitrogen are strictly adhered to. In addition, all necessary precautions must be taken to prevent contamination of oxygen and nitrogen systems. These precautions are discussed in the following paragraphs.

OXYGEN

Aviator's breathing oxygen is supplied in two types (I and II). Type I is gaseous oxygen and type II is liquid oxygen. A brief description of gaseous oxygen, including its characteristics and production methods, is presented in chapter 7. Safety precautions applicable to the handling of oxygen for oxyacetylene welding are also discussed in chapter 7. The following safety precautions should be strictly adhered to for the safe operation of gaseous oxygen servicing trailers:

1. Complete familiarity with the trailer is a basic prerequisite to safe operating techniques. Therefore, only qualified operators should operate the trailer.

2. Never permit oil, grease, or readily combustible materials to come in contact with oxygen cylinders, valves, regulators, gages, or fittings.

3. The servicing hose and connection of the system to be serviced should be thoroughly inspected prior to servicing, and any trace of oil, grease, or foreign material carefully removed.

4. The servicing hose should always be bled prior to use to insure expulsion of all loose foreign matter from the line.

5. Open all valves slowly.

6. Always know the pressure existing in the oxygen system to be filled and the pressure in all cylinders to be used before commencing an operation.

7. Insure that the line valve on the discharge end of the servicing hose is closed at all times when not actually servicing a system.

8. The charging hose must never be tightly stretched to reach a connection. Position the trailer so the service hose is not under tension during a service operation.

9. When disconnecting the service hose from a fitting, loosen the connection slowly to prevent rapid bleeding of the trapped oxygen.

10. In locations where inside storage is available, the trailer should be stowed away from the weather during periods of nonuse. Where inside storage is impractical, a canvas cover should be fabricated to protect the manifold components and service hose assembly.

Liquid oxygen, commonly referred to as LOX, is normally obtained by a combined cooling and pressurization process. When the temperature of gaseous oxygen is lowered to -182°F under about 720 psi pressure, it will begin to form into a liquid. When the temperature is lowered to -297°F, it will remain a liquid under normal atmospheric pressure.

Once converted into a liquid, oxygen will remain in its liquid state as long as the temperature is maintained below -297°F. The liquid has an expansion ratio of 862 to 1, which means that one volume of liquid oxygen will expand 862 times when converted to a gas at atmospheric pressure. Thus, 1 liter of liquid oxygen produces 862 liters of gaseous oxygen.

Liquid oxygen can be handled safely and easily by observing the following safety precautions:

1. Never allow liquid oxygen to contact the skin. The extreme low temperature of the liquid will immediately freeze the area and severe frostbite results. Obtain first aid immediately if splashed with liquid oxygen.

2. Personnel exposed to accidental spillage of liquid oxygen must wear protective clothing to prevent skin and vision damage because of freezing.

3. Only qualified or authorized personnel being trained and under the supervision of qualified personnel should be allowed to operate liquid oxygen equipment.

4. NO SMOKING applies at all times. Oxygen gas will not burn, but it supports combustion of any material which does burn.

5. Keep liquid oxygen away from absorbent materials, loose clothing, or rags. These materials can trap oxygen gas and later be ignited by a spark from a cigarette or match.

6. When in use, keep the equipment in a well-ventilated area away from all gasoline, kerosene, oil, or grease.

7. Never confine liquid oxygen in any piping or container. The pressure buildup when the liquid expands to gas will rupture any piping and tubing.

Liquid oxygen must be kept free of contamination; otherwise, serious consequences may result. A contaminated supply may cause noxious and nauseating odors which may adversely affect the pilot's efficiency or cause malfunctions in the liquid oxygen system. For these reasons, all personnel working with liquid oxygen servicing equipment should take every possible precaution to maintain the quality of the liquid oxygen supply and prevent contaminants from being introduced into the supply during the storage and transfer operations.

To prevent liquid oxygen contamination:

1. Never store liquid oxygen in or around areas in which odors of any type may be absorbed by the liquid oxygen. It should be remembered that liquid oxygen has a high affinity for many gaseous compounds. An example of a poor storage practice is parking the liquid oxygen trailers in the area behind the flight line where jet aircraft are parked.

2. Extreme care should be taken to insure that dirty or oily equipment is never used with liquid oxygen equipment.

3. Keep the liquid oxygen transfer hose filler valve dust cover in place at all times except when actually in use.

NOTE: This dust cover is usually attached to the hose with a chain. This insures that the cover will be readily available at all times.

4. Liquid oxygen storage tanks and servicing trailers should never be allowed to go dry and be exposed to the atmosphere. When the liquid oxygen equipment is emptied for any reason, it should be closed to the atmosphere in order to prevent the introduction of water vapor or odor.

NOTE: Liquid oxygen storage tanks and servicing trailers which have been allowed to run dry must be purged in accordance with the existing directives.

NITROGEN

For all practical purposes, nitrogen is considered to be an inert gas. (Inert is defined as chemically inactive; not combining with other chemicals.) It is not completely inert like helium or argon, for there are many nitrogen compounds, such as nitrate used in fertilizers and explosives. However, nitrogen is very slow to combine chemically with other elements under normal conditions. Nitrogen, as a gas, supports no fires, no living things, and causes no rust or decay of most of the things with which it comes in contact. Due to these qualities, its use is preferred over compressed air in many pneumatic systems, especially aircraft and missile systems.

There are two classes of gaseous nitrogen and both are available in military supply. Class I is oil free; that is, it is compressed by a water lubricated (or nonlubricated) pump. This class is commonly referred to as water pumped nitrogen. Class II is defined as oil tolerant nitrogen. This class is compressed with an oil lubricated pump and is, therefore, referred to as oil pumped nitrogen

Class I (water pumped) nitrogen is most commonly used in aviation. Class II (oil pumped) nitrogen can be dangerous in certain situations. For example, if oil pumped nitrogen is used in tires, an oil film (hydrocarbon) may build up on the inside walls of the tire, soaking into the pores of the rubber. This should not hurt synthetic rubber and it does not present a combustion hazard in the presence of inert nitrogen. However, there comes a time when nitrogen is not available and compressed air, the approved alternate, is used to inflate the tire. The hydrocarbon film is then in contact with compressed air which is definitely a combustible mixture. This is an undesirable practice and should be avoided.

One of the greatest potential hazards when oil pumped nitrogen is available is the possibility that someone will use it to purge an oxygen system. Oxygen will not burn, but it supports and accelerates combustion and will cause oil to burn more easily and with greater intensity. Therefore, oil pumped nitrogen must never be used to purge oxygen systems. When the small amount of oil remaining in the nitrogen comes in contact with the oxygen, an explosion may result.

Nitrogen gas will not support life, and when released in a confined space will cause asphyxia (the loss of consciousness as a result of too little oxygen and too much carbon dioxide in the blood).

In the liquid state, nitrogen is colder than liquid oxygen. Under normal atmospheric pressure the temperature of liquid nitrogen is -320°F. Therefore, if it is exposed to air, oxygen from the air may condense into the liquid nitrogen. If exposure is allowed to continue for any length of time, the oxygen content of the liquid nitrogen becomes appreciable, and the liquid requires the same precautions in handling as liquid oxygen.

The following safety precautions should be strictly observed for safe operation of the high-pressure and liquid nitrogen service vehicle:

1. Only qualified operators should operate the vehicle.
2. Always wear protective clothing when handling liquefied gas. Wear goggles, loose fitting leather gloves, and long sleeves when handling liquid in a container or drawing liquid from a valve.
3. Store and use liquid nitrogen in a well-ventilated place. Without adequate ventilation, expanding nitrogen will lower the oxygen content in the air. Air with low oxygen concentration can cause dizziness, unconsciousness, or even death.
4. Dispose of liquid nitrogen in an outdoor area where its cold temperature cannot cause damage and where it will evaporate rapidly.
5. Do not touch supply lines without protective hand coverings; unprotected hands will stick to the line and attempts to withdraw from it will tear the flesh.
6. Various parts of the system will contain gaseous nitrogen at pressures up to 3,000 psi. The precautions and procedures that apply are the same as those for handling compressed air at the same pressures.

ENVIRONMENTAL POLLUTION CONTROL

Environmental pollution is the condition which results from the presence of undesirable chemical, physical, or biological agents in the air, water, or soil. The presence of these undesirable agents so alters the natural environment that an adverse effect is created on human health and comfort, fish and wildlife, plant life, structures, and equipment to the extent of producing economic loss, impairing recreational opportunity, and marring natural beauty. United

States concern with the problems of environmental quality is of the highest priority. Particularly in the last few years, this nation has come to realize that, if we are to continue to rely on the air, land, and water resources of this earth—upon which our survival depends—we must treat these resources with care and respect. Therefore, we must clean up existing pollution and take the necessary measures to prevent or, at least, to minimize further pollution.

As a result, the entire nation is placing great emphasis on this problem. Government (federal, state, and local), industry, military, other groups, and individuals are and must continue to be very much concerned with this problem. In line with this, a recent addition to the requirements for the ASH includes several factors concerning environmental pollution control.

These requirements pertain primarily to pollution caused by petroleum products. This includes pollution resulting from the burning of fuels in internal combustion engines and the disposal or spillage of petroleum products on the water or ground.

FUELS

As discussed previously in this chapter, gasoline and diesel are the most common types of fuels used in support equipment. Jet propulsion fuels (JP-4 and JP-5) are used in gas turbine power equipment and may be used in multifuel engines which are designed to use several different types of fuel. These fuels are all products of petroleum which is a complex mixture of various chemical compounds, commonly known as hydrocarbons. Hydrocarbon compounds consist of the elements hydrogen and carbon. Traces of nitrogen, sulfur, and other elements may also be presented in petroleum products.

In the process of fuel consumption in internal combustion engines, a portion of the fuel is unburned. The amount of unburned fuel depends to a great extent on the condition of the engine. Since these are unburned gases, this type of pollutant is referred to as hydrocarbons. These hydrocarbon emissions combine with oxides of nitrogen and sunlight to form smog.

The burned gases resulting from fuel combustion contain several pollutants. The most widely known of these is carbon monoxide. Other pollutants contained in these gases include oxides of nitrogen and oxide of sulfur. Some of these pollutants are more of a health problem than others; however, they are all detrimental to the quality of the environment.

In some cases, the additives added to fuels for various reasons result in pollution. For example, lead is added to some gasoline to increase octane rating, which prevents engine knock. Lead in gasoline has two adverse effects. First, lead emissions into the air can be harmful to health; and, second, lead deposits inhibit the use of other pollution control devices. For this reason, unleaded and low lead content gasoline should be used if possible. Some high compression engines require leaded gasolines; however, substitute additives are being tested for adverse effects. In the meantime, all new gasoline engines are designed to be operated on 91 octane (no lead) gasoline.

These harmful gases are emitted through the engine exhaust and can also be emitted through the engine crankcase. During the combustion process, gases seep past the piston rings into the crankcase. The seepage is commonly referred to as blowby and, if not arrested by some type of antipollution device, is emitted to the atmosphere.

All new equipments will contain some type or types of antipollution devices. It is very possible that change kits will be provided for some of the older types of equipment. These devices will probably be similar to those used on the late model automobiles. For example, the positive crankcase ventilation (PCV) system is used on all late model automobiles. Basically, this system returns vapors from the crankcase to the intake manifold. Here they are reburned, thus helping to reduce the air pollution problem. Possible future equipment includes the recirculation of a small amount of exhaust gas to lower combustion temperatures. This reduces the formation of oxides of nitrogen. Also in the future is the catalytic converter which will convert most of the hydrocarbons and carbon monoxide in the exhaust to water vapor and carbon dioxide.

In the meantime, it is most important that internal combustion engines are maintained in excellent mechanical condition. Inspections and preventive maintenance intervals must be strictly adhered to.

FUEL AND OIL SPILLAGE

Pollution of the water and ground by oil or other petroleum products is one of the most

visible and one of the most damaging forms of pollution. The Navy's problems are not those generally caused by massive oil spills but those small spills in harbors. The discharge of only a few gallons of oil in certain locations can seriously affect marine life and waterfowl, render beaches useless, cause fire and explosion, and kill plantlife. In certain areas, such spills can contaminate water supply systems.

To prohibit this form of pollution, the Navy must conform to the provisions of the Oil Pollution Acts of 1924 (as amended) and 1961. The ASH should be familiar with the provisions of these Acts.

The Oil Pollution Act of 1924 (as amended) stipulates that, except in case of an emergency imperiling life or property, or unavoidable accident, collision or stranding, and except as may otherwise be permitted by certain regulations, it shall be unlawful for any person (including any officer or employee of the United States) to discharge or permit the discharge of oil of any kind or form (including fuel oil, oil sludge, and oil refuse) by any method, means, or manner into or upon the coastal navigable waters of the United States. Coastal navigable waters of the United States means all portions of the sea within the territorial jurisdiction of the United States, and waters navigable in fact in which the tide ebbs and flows.

The Oil Pollution Act of 1961 extends the provisions of the 1924 Act by prohibiting the discharge into the sea of oil and water containing oil within 50 miles of any land, and establishes certain prohibited zones which in some areas extend as far as 150 miles from land. In accordance with the provisions of the Act of 1961, the discharge of oil or any oily mixture is not deemed unlawful when such action is required (1) for the safety of the ship, (2) for the prevention of damage to the ship or its cargo, and (3) for the saving of life at sea. In addition, the escape of oil or an oily mixture is not considered unlawful if it results from damage to the ship or from unavoidable leakage, provided that all reasonable precautions have been taken, after occurrence of the damage or discovery of the leakage, for the purpose of preventing or minimizing the escape.

CHAPTER 5

TOOLS AND HARDWARE

The ASH must have a well-rounded knowledge of many different types of tools and the purpose for which they are designed. In addition, he must have a thorough knowledge of the various types of hardware—nuts, bolts, rivets, etc.—used in the construction of support equipment. The first section of this chapter covers the use and care of common handtools and some of the special tools required by the ASH in the performance of his duties. The last section of the chapter is devoted to various items of hardware with which the ASH is concerned.

TOOLS

An ASH is only as good as he is proficient with the tools of his trade. Without tools and equipment with which to work, even the most experienced ASH is rendered ineffective.

Each ASH in the work center is usually issued a toolbox of common or basic handtools. It is his responsibility to keep these tools in good condition and ready for use. At the time of issue of the toolbox, he is also usually provided with a copy of his tool inventory. By means of this inventory he can quickly ascertain if his toolkit is complete.

Special tools for which the ASH has only occasional use are kept in a central place from which he may draw them as needed.

As can be appreciated from the foregoing, there is much the ASH needs to know about procurement, issue, care, and accounting for common and special tools as well as using them to perform repair and maintenance functions on ground support equipment.

PROCUREMENT

Generally, each activity has a centrally located toolroom which procures and manages tools for the activity as a whole. This allows for better control of the tools.

An activity's allotted amount of handtools is in accordance with a predetermined allowance. This allowance is established by the Allowance List, NavAir 00-35QG-016, Consumable General Support Equipment for all Types, Classes, and Models of Aircraft. This lists the handtools necessary for the support of aircraft and, therefore, includes most of the handtools required for the maintenance of the support equipment required for the support of aircraft.

Whenever the number of tools in the activity falls below a certain minimum, the central toolroom supervisor reorders to replenish his stock. The quantity status of tools on hand is determined by regular inventories.

ISSUE

Tools are issued by the central toolroom in two ways. Handtools are usually issued as a kit and contained in a toolbox. This is a semipermanent issue, and the mechanic or technician keeps the tools as long as he is required to have a toolbox. Other tools are kept in the toolroom and are checked out on an as-needed basis but are normally returned to the toolroom at the end of each workday.

Issue of Handtools

When it is desired that an ASH have a toolkit assigned to him on a custody basis, the Support Equipment Supervisor will notify the toolroom supervisor to issue an ASH toolbox and kit to the person concerned. This kit contains enough small handtools common to the ASH rating so that the person can do possibly 90 percent of his work with the tools contained in the kit and by use of available shop equipment.

The central toolroom normally prepares an inventory of the tools issued to persons in each rating. This inventory is prepared in duplicate, and one copy is furnished the worker. It should be kept in the toolbox in an oil- and grease-resistant envelope if possible. The worker's copy of the inventory is useful to the ASH in accounting for his tools after each job and also for complying with the periodic inventories that the central toolroom will require.

The ASH having custody of a toolkit must prevent the loss or damage of tools, insofar as

practicable. Although handtools are classified as consumable items, most are very expensive and must be paid for by the maintenance activity. During delays or standbys, the ASH should check over the tools in his toolbox and perform whatever maintenance on them that is possible.

Periodic inventory of tools serves two distinct purposes: First, it provides the central toolroom with an up-to-date count of the actual number of tools of each type still on hand and usable; and second, it provides a means of evenly dividing the tools again. As time goes by in a support equipment work center, a given ASH will accomplish maintenance tasks in the company of first one and then another of the personnel assigned to the work center. This results in an inevitable scrambling of tools—one worker will gain tools and others will lose them. For this reason, all the tools in a given box may be identified by a number corresponding to the box number, either etched or painted on the tools.

Issue of Special Tools

This category of tools is not part of the individual toolkit inventory. Special tools are normally kept in the central toolroom and signed out as needed. A tool falls into the special tool category for the following five main reasons:

1. It is an item of Special Support Equipment that was designed, manufactured, procured, stocked, and issued for the purpose of maintaining one certain model or type of equipment.
2. It is a seldom used tool, and the majority of time it would merely take up room in the toolboxes. However, when needed, its use is essential in the maintenance of support equipment.
3. It is often a high cost item. Since fewer are purchased, the central location is necessary to permit better utilization.
4. The awkward size and shape of the tool make it extremely difficult, if not impossible, to issue one to each ASH to carry around in his toolkit.
5. It is an instrument type of tool that depends upon precise calibration for its usefulness. It could be knocked out of adjustment if subjected to the normal handling of an ASH toolbox.

Of course, a special tool may be covered under more than one or even all of the foregoing categories.

Each time a special tool is needed, the worker needing it has to check it out by signing a temporary custody chit. When he returns the tool at the end of the day or at the completion of the job, he has an opportunity to report any trouble with the tool. The toolroom supervisor may then be able to cause the necessary repairs to be made. A secondary benefit is to be able to refer to past records and see who used the tool last and reported no discrepancy. It may be possible to fix responsibility for careless use of tools in some cases.

HANDTOOLS

The handtools discussed in this section are those which the ASH may have in his personal toolbox. Even though other tools may also be classed as handtools, they are discussed in the succeeding section under "Special Tools" if they are not normally carried in the toolbox.

NOTE: Two Rate Training Manuals—Tools and Their Uses, NavPers 10085 (Series), and Airman, NavPers 10307 (Series)—contain descriptions and illustrations of most tools used by the ASH, together with detailed instructions for using them. The material covered in this chapter is intended to supplement, rather than repeat, the information given in these training manuals and should be studied in conjunction with them.

Before discussing the tools individually, a few comments on the care and handling of handtools in general might be appropriate. The condition in which an ASH maintains his assigned tools determines his efficiency as well as affects the judgment that his superiors pass upon him in his day-to-day work. A mechanic or technician is always judged heavily by the manner in which he handles his tools.

Each ASH should keep all his assigned tools in his toolbox when he is not actually using them. He should have a place for every tool, and every tool should be kept in its place. All tools should be cleaned after every use and before being placed in the toolbox. If they are not to be used again the same day, they should be oiled with a light preservative oil to prevent rusting. Tools that are being used at a workbench or at a machine should be kept in easy reach of the worker, but should be kept where they will not fall or be knocked to the deck. Tools should not be placed on finished parts of machines.

Handtools may be classed according to the tasks they perform. These classifications are striking tools, cutting tools, turning tools, holding tools, riveting tools, and miscellaneous tools.

Striking Tools

Generally speaking, this group is composed of various types of hammers and mallets, all of which are used to apply a striking force where the force of the hand alone is insufficient. The striking tools most commonly used by the ASH are ball-peen hammers, plastic mallets, and planishing hammers. Information concerning the selection, use, care, and safety of ball-peen hammers and plastic mallets is contained in Tools and Their Uses, NavPers 10085 (Series). The planishing hammer is described briefly in the following paragraphs.

PLANISHING HAMMER.—The planishing hammer has two metal heads with slightly convex faces. The heads may be round, square, or a combination of both. Planishing hammers are lighter than most hammers and are primarily used by the ASH to smooth out metal surfaces that have been bent out of shape.

In planishing, place the metal on a smooth surface, such as a forming block or stake, and lightly strike the irregularities with the face of the hammer until smooth. Care must be taken to prevent stretching of the metal by striking with glancing blows. If an oil can (excess metal which will pop up or down if pressed with the fingers) seems to be forming during planishing procedures, it may be necessary to shrink the metal. Shrinking the metal is accomplished by the use of glancing blows in the opposite direction of the blows that caused the stretching. Figure 5-1 shows a planishing hammer being used. Notice the metal is being backed up by a stake.

Cutting Tools

Included in this group of tools are diagonal cutting pliers, files, hacksaws, twist drills, countersinks, chisels, and the various types of snips used by personnel to trim or cut material by hand.

Adequate coverage on the selection, care, and use of cutting tools is contained in Tools and Their Uses, NavPers 10085 (Series), and Airman, NavPers 10307 (Series), and is therefore not repeated here.

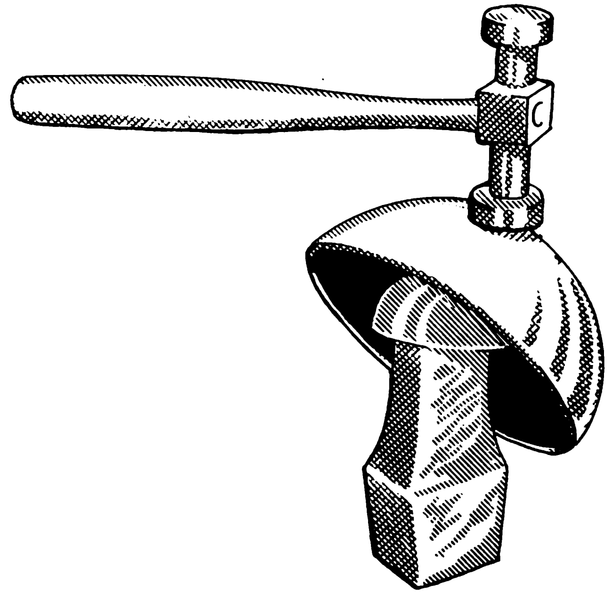

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Figure 5-1.—Using a planishing hammer.

Turning Tools

Turning tools are the tools used for turning nuts, bolts, and screws. Those of primary interest to the ASH are the socket wrench sets, which consist of several types of handles and bar extensions, universals, adapters, and a variety of sockets; combination wrenches, open end on one end and box end on the other; adjustable wrenches, commonly referred to as "knuckle busters"; common blade screwdrivers, for use on conventional slotted screws; crosspoint blade screwdrivers, for use on recessed head Phillips and Read and Prince type screws; and Bonney and split box wrenches used for tightening hydraulic fittings.

Adequate coverage on the selection, use, care, maintenance, and safety for turning tools is contained in Tools and Their Uses, NavPers 10085 (Series), and Airman, NavPers 10307 (Series), and therefore is not repeated here.

Holding Tools

Holding tools refer to the various types of pliers employed to hold, secure, clamp, twist, or bend in the performance of maintenance. Those of primary concern to the ASH are vise grip, channel-lock, duckbill, needle-nose, and wire twister pliers.

Adequate coverage on their selection, use, care and safety is contained in Tools and Their Uses, NavPers 10085 (Series), and Airman, NavPers 10307 (Series), and is therefore not repeated here.

Riveting Tools

The ASH frequently requires riveting tools for the structural repair of support equipment. These tools may be a part of his regular toolkit; however, in most instances these tools are included in separate toolboxes made up especially for structural repair. Some of the most common riveting tools are described in the following paragraphs. Riveting guns are discussed later in this chapter.

ROTARY RIVET CUTTERS.—In case one cannot obtain rivets of the required length, rotary rivet cutters (fig. 5-2) are used to cut longer rivets to the desired length. When using the rotary rivet cutter, insert the rivet part way into the correct diameter hole, place the required number of shims (shown as staggered, notched strips in the illustration) under the head, and squeeze the handles. The compound action from the handles rotates the two discs in opposite directions. Rotation of the discs shears the rivet smoothly to give the correct length (as determined by the number of shims inserted under the head). For cutting large rivets, place one of the tool handles in a vise, insert the rivet in the hole, and shear it by pulling the free handle. If this tool is not available, diagonal cutting pliers can be used as an emergency cutter although the sheared edges will not be as smooth and even as when cut with the rotary rivet cutter.

RIVET SET.—A rivet set is a tool equipped with a die for driving a particular type of rivet. Rivet sets are used in both hand and pneumatic hammer riveting methods. Rivet sets are available to fit every size and shape of rivet head. The ordinary hand set is made of 1/2-inch-diameter carbon steel about 6 inches long and in knurled to prevent slipping in the hand. Only the face of the set is hardened and polished. Sets for the oval head rivets (universal, round, and brazier) are recessed (or cupped) to fit the rivet head. In selecting the correct set, be sure that it will provide the proper clearance between the set and the sides of the rivet head and between the surfaces of the metal and the set. Flush or flat sets are used for countersunk and flathead rivets. In order to set flush rivets

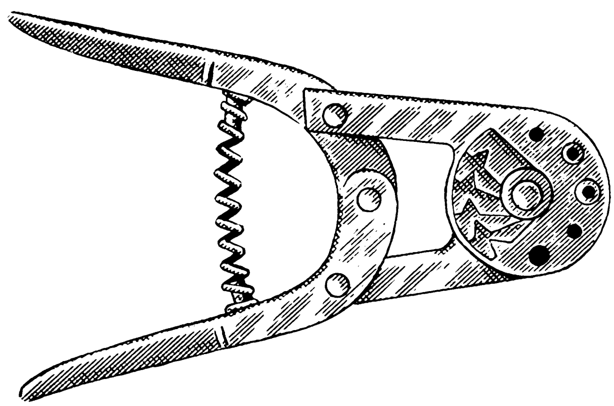

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Figure 5-2.—Rotary rivet cutter.

properly, the flush sets should be at least 1 inch in diameter.

Special sets, called "draw" sets, are used to "draw up" the sheets being riveted in order to eliminate any opening between them before the rivet is bucked. Each draw set has a hole 1/32 inch larger than the diameter of the rivet shank for which it was made. Sometimes, especially in handworking tools, the draw set and the rivet header are incorporated into one tool. The header part consists of a hole sufficiently shallow for the set to expand the driven rivet "bucktail" and form a head on it when the set is struck with a hammer. Figure 5-3 illustrates a rectangular-shaped handset which combines the draw and header sets and a flush set used with the pneumatic hammer.

Sets used with pneumatic hammers (rivet guns) are provided in many sizes and shapes to fit the type and location of the rivet. These sets are the same as the hand rivet sets except that the shank is shaped to fit into the rivet gun. The sets are made of high-grade carbon tool steel and are heat treated to provide the necessary strength and wear resistance. The tip or head of the rivet set should be kept smooth and highly polished at all times to prevent marring of rivet heads.

BUCKING BARS.—Bucking bars are tools used to form bucktails (the head formed during riveting operations) on rivets. They come in many different shapes and sizes, as illustrated in figure 5-4. Bucking bars are normally made from an alloy steel similar to tool steel. The

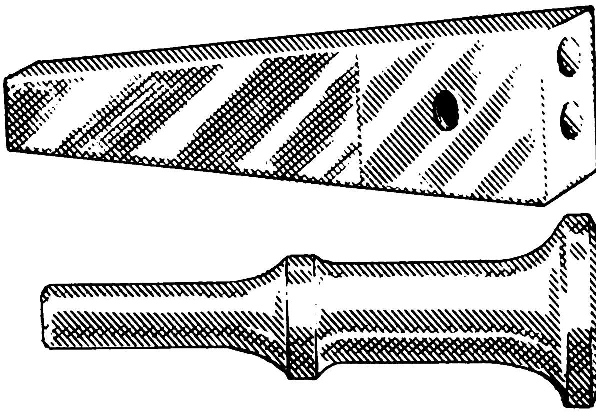

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Figure 5-3.—Rivet sets.

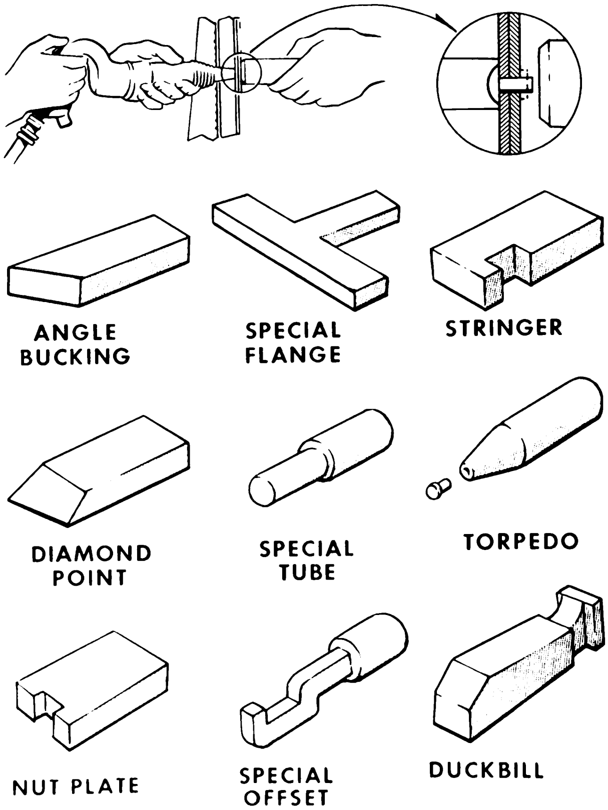

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Figure 5-4.—Bucking bars.

particular shape to be used depends upon the location and accessibility of the rivet to be driven. The size and weight of the bar depend on the size of the rivet to be driven. Under certain circumstances, and for specific rivet installations, specially designed bucking bars are manufactured locally. These bars are normally made of tool steel. The portion of the bar designed to come in contact with the rivet has a polished finish. This helps to prevent marring of formed bucktails. Bucking bar faces must be kept smooth and perfectly flat and the edges and corners rounded at all times.

NOTE: Never hold a bucking bar in a vise unless the vise jaws are equipped with protective covers. This will prevent marring of the bucking bar.

A satisfactory rivet installation depends largely on the condition of the bucking bar and the ability of the ASH using it. If possible, hold the bucking bar in such a manner that will allow the longest portion of the bar to be in line with the rivet. The ASH should hold the bucking bar lightly but firmly against the end of the rivet shank so as not to unseat the rivet head. The inertia of this tool provides the force that bucks (upsets) the rivet, forming a flat, head-like bucktail.

HOLE FINDER.—A hole finder is a tool used to transfer existing holes in structural members or sheet metal to replacement sheet metal or patches. The tool has two leaves parallel to each other and fastened together at one end. The bottom leaf of the hole finder has a teat installed near the end of the leaf which is aligned with a bushing on the top leaf, as illustrated in figure 5-5. The desired hole to be transferred is located by fitting the teat on the bottom leaf of the hole finder into the existing rivet hole. The hole in the new part is made by drilling through the bushing on the top leaf. If the hole finder is properly made, holes drilled in this manner will be perfectly aligned. A separate duplicator must be provided for each diameter of rivet to be used.

TEMPORARY SHEET METAL FASTENERS.—There are several types of sheet metal fasteners used to temporarily secure parts in position for drilling and riveting and to prevent slipping and creeping of the parts. C-clamps, machine screws, and Cleco fasteners are frequently used in the Navy. (See fig. 5-6.) Of the three, the Cleco is the most popular. Cleco fasteners come in sizes ranging from 1/16 to

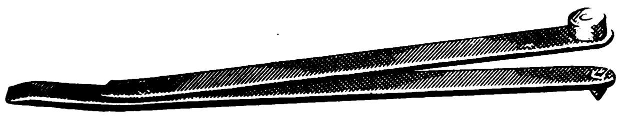

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Figure 5-5.—Hole finder.

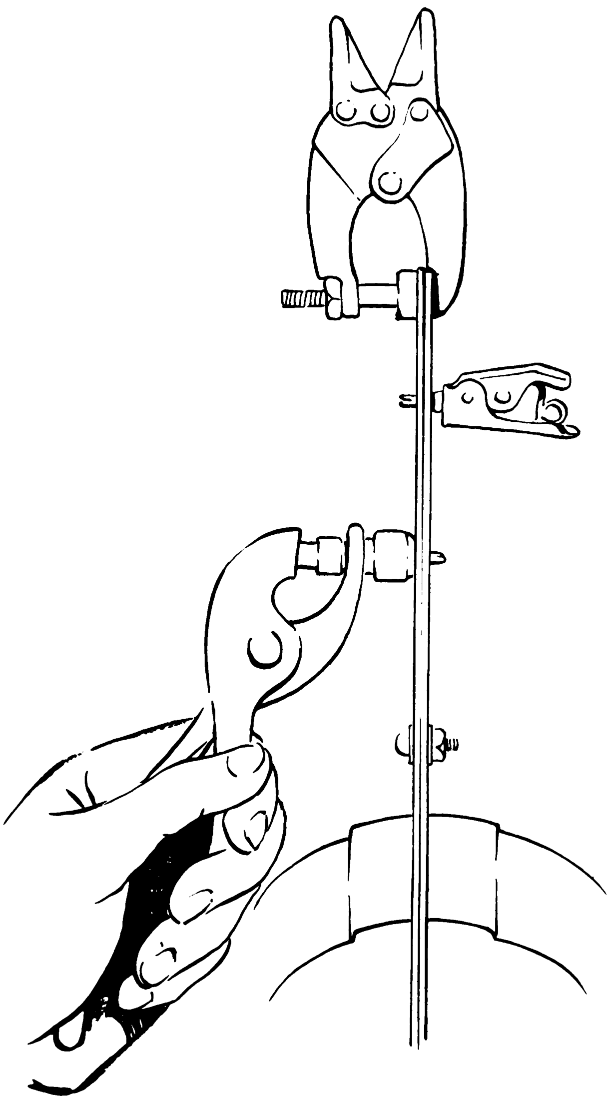

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Figure 5-6.—Sheet metal temporary fasteners.

3/8 inch. The size is normally stamped on the fastener, but may also be recognized by the following color code:

1/16 inch	black
3/32 inch	cadmium
1/8 inch	copper
5/32 inch	black
3/16 inch	brass
1/4 inch	green
3/8 inch	red

The Cleco fastener is installed by compressing the spring with Cleco pliers (forceps). With the spring compressed, the pin of the Cleco is inserted in the drilled hole. The compressed spring is then released, allowing spring tension on the pin of the Cleco to draw the materials together. Clecos should be stored on a U channel plate to protect the pins of the fasteners. Clecos stored at random among heavy tools will become useless due to bent pins.

Miscellaneous Tools

There are several miscellaneous items that should be included in the ASH toolbox. These include such items as flashlights, mechanical fingers, and inspection mirrors. These items are described in Tools and Their Uses, NavPer 10085 (Series). Two other items which should be included are a steel scale and a scriber. These tools are described in the following paragraphs.

STEEL SCALE.—The steel scale (fig. 5-7) is a measuring device that is usually found in the ASH toolbox. It is graduated in divisions of 1/8 and 1/16 inch on one side and 1/32 and 1/64 inch on the other. The steel scale most commonly used is 12 inches long.

Measurements are taken with a steel scale by holding it on its edge on the surface of the subject being measured. This will prevent making errors which might be caused by the thickness of the scale. Such thickness causes the graduations to be a slight distance away from the surface of the object. Measurements are read at the graduation which coincides with the distance to be measured.

NOTE: Several other types of measuring tools are occasionally used by the ASH. These include such items as calipers, micrometers, and dial indicators. These measuring tools are adequately covered in Tools and Their Uses, NavPers 10085 (Series) and are therefore not described here.

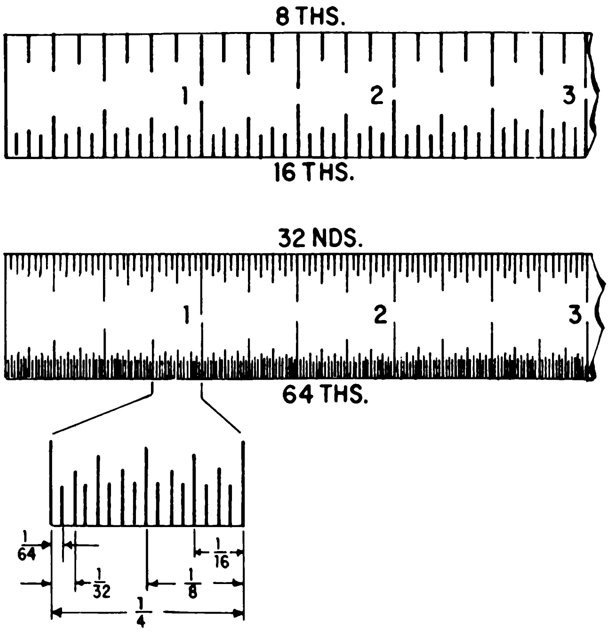

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Figure 5-7.—Steel scale.

SCRIBER.—The scriber is a round, slender instrument made from tool steel. Both ends have sharp points; however, one is bent to form a 90-degree angle, as illustrated in figure 5-8.

The scriber is used by the ASH while laying out a pattern on sheet metal. Prior to laying out the pattern, metal surfaces should first be stained with a layout dye. If layout dye is not available, zinc chromate primer may be used as a substitute. A scriber is used only on the portion of the layout that requires cutting. All other layout lines are drawn, using a contrasting color pencil.

SPECIAL TOOLS

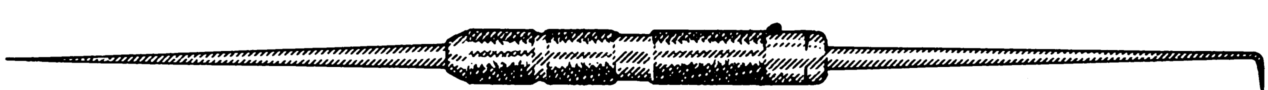
The category of special tools is defined previously in this chapter. The use of special tools which are designed and furnished by the manufacturer for a specific model of equipment is explained in the appropriate Instructions Manual. Included in this category are spanner wrenches and strap wrenches. These tools are covered adequately in Tools and Their Uses, NavPers 10085 (Series). Some of the other special tools commonly used by the ASH are discussed in the following paragraphs. These tools are usually available in limited quantity from the main toolroom.

Torque Wrenches

There are times when, for engineering reasons, a definite pressure must be applied to a nut, bolt, screw, or other fastener. In such cases a torque wrench must be used. The torque wrench is a precision tool consisting of a torque-indicating handle and appropriate adapter or attachments. It is used to measure the amount of turning or twisting force applied to a nut, bolt, or screw.

The three most commonly used torque wrenches are the Deflecting Beam, Dial Indicating, and Micrometer Setting types (fig. 5-9). When using the Deflecting Beam and the Dial Indicating torque wrenches, the torque is read visually on a dial or scale mounted on the handle of the wrench.

To use the Micrometer Setting type, unlock the grip and adjust the handle to the desired setting on the micrometer scale, then relock the grip. Install the required socket or adapter to the square drive of the handle. Place the wrench assembly on the nut or bolt and pull in a clockwise direction with a smooth steady motion. (A fast or jerky motion will result in an improperly torqued unit.) When the torque applied reaches the torque value indicated on the handle setting, the handle will automatically release or "break" and move freely for a short distance. The release and free travel is easily felt, so there is no doubt about when the torquing process is complete.



AM.301

Figure 5-8.—Sheet metal scriber.

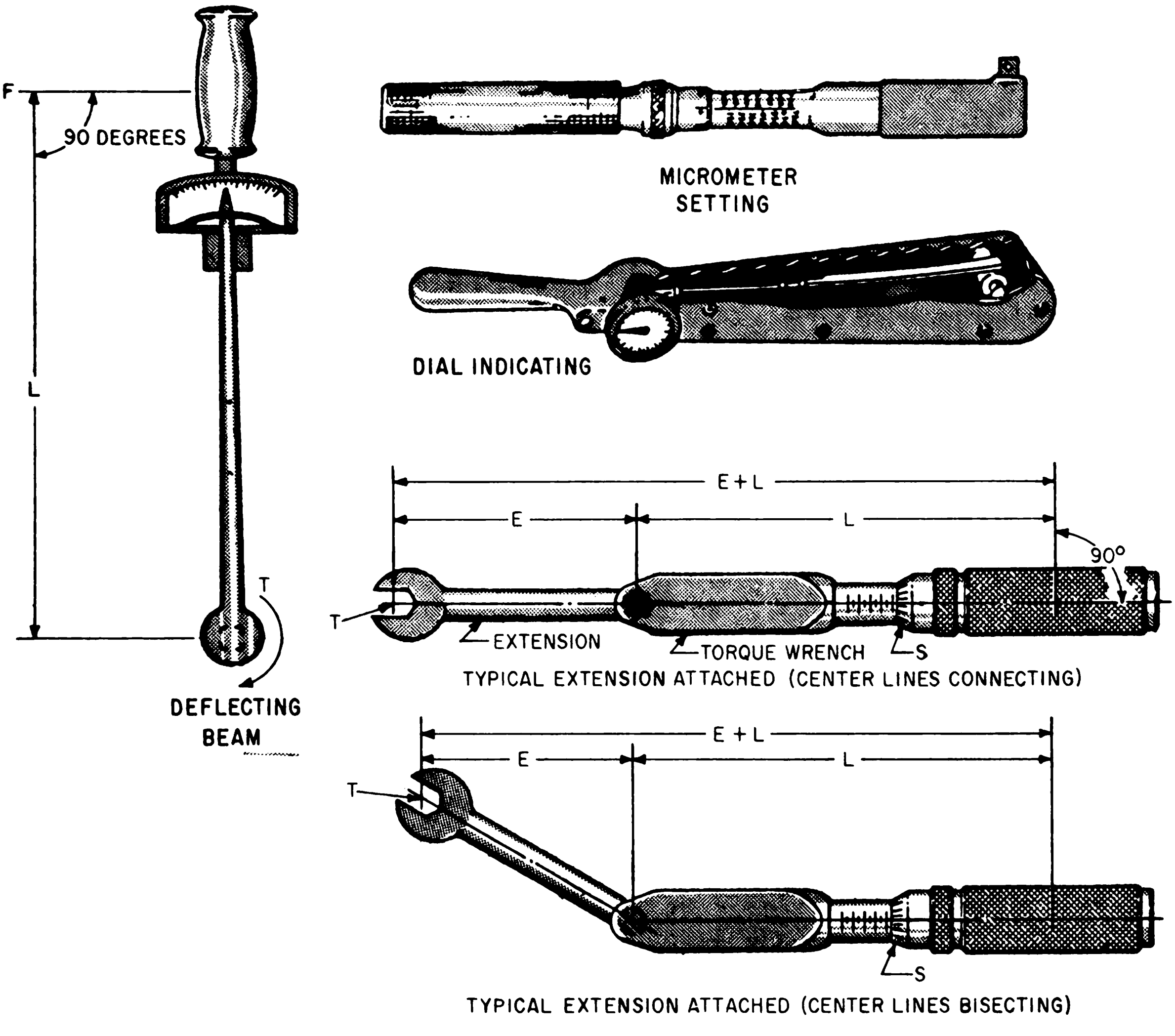


Figure 5-9.—Torque wrenches.

To assure getting the correct amount of torque on the fasteners, all torque handles must be tested at least once a month or more often if usage indicates it is necessary.

The following precautions should be observed when using torque wrenches:

1. Do not use the torque wrench as a hammer.
2. When using the Micrometer Setting type, do not move the setting handle below the lowest torque setting. However, it should be placed at its lowest setting prior to returning to storage.
3. Do not use the torque wrench to apply greater amounts of torque than its rated capacity.
4. Do not use the torque wrench to break loose bolts which have been previously tightened.
5. Never store a torque wrench in a toolbox or in an area where it may be damaged.

TORQUE VALUES.—Torquing can be described as the twisting stress that is applied to the fasteners to secure components together. These fasteners can be nuts, bolts, studs, clamps, etc. Torque values for these fasteners

are expressed in inch-pounds or foot-pounds. Unless otherwise stated, all torque values should be obtained with the manufacturer's recommended thread lubricant applied to the threads.

Torque values are usually listed in the appropriate section of the applicable Instructions Manual. However, in case there is no torque specified, the torque values in table 5-1 can be used as a guide in tightening nuts, bolts, and screws. Using the proper torque allows the structure to develop its design strength and greatly reduces the possibility of failure due to fatigue. One word of caution—never rely on memory for torque information, but look up the correct torque value each time it is needed. A nut or bolt that is not torqued to the proper value may cause damage to the component or equipment.

The proper procedure is to tighten at a uniformly increasing rate until the desired torque is obtained. In some cases, where gaskets or other parts cause a slow permanent set, the torque must be held at the desired value until the material is seated. When applying torque to a series of bolts on a flange or in an area, select a median value. If some bolts in a series are torqued to a minimum value and others to a maximum, force is concentrated on the tighter bolts and is not distributed evenly. Such unequal distribution of force may cause shearing or snapping of the bolts.

Torque wrench size must be considered when torquing. The torque wrenches are listed according to size and should be used within this recommended range. Use of larger wrenches which have too great a tolerance results in

Table 5-1.—Torque value in inch-pounds for standard nuts, bolts, and screws.

Wrench size	Standard nuts, bolts, and screws		
	Bolt, stud, or screw size	Tension type nuts AN310 and AN365	Shear type nuts AN320 and AN364
1/4	4-48	4-5.5	2.5-3.5
5/16	6-40	7.5-11	4.5-6.5
11/32	8-36	12-15	7-9
3/8	10-32	20-25	12-15
7/16	1/4-28	50-70	30-40
1/2	5/16-24	100-140	60-85
9/16	3/8-24	160-190	95-110
5/8	7/16-20	450-500	270-300
3/4	1/2-20	480-690	290-410
7/8	9/16-18	800-1,000	480-600
15/16	5/8-18	1,100-1,300	660-780
1 1/16	3/4-16	2,300-2,500	1,300-1,500
1 1/4	7/8-14	2,500-3,000	1,500-1,800
1 7/16	1-14	3,700-5,500	2,200-3,300

NOTE: AN specification numbers may be superseded by MS specification numbers.

inaccuracies. When an offset extension wrench is used with a torque wrench, the effective length of the torque wrench is changed. The torque wrench is so calibrated that when the extension is used, the indicated torque (the torque which appears on the dial or gage of the torque wrench) may be different from the actual torque that is applied to the nut or bolt. Therefore, the wrench must be preset to compensate for the increase when an offset extension wrench is used.

Occasionally, it is necessary to use a special extension or adapter wrench together with a standard torque wrench. In order to arrive at the resultant required torque limits, the following formula should be used

$$S = \frac{T \times L}{(E + L)}$$

Where:

S = Reading of setting on torque wrench.

T = Recommended torque on part.

L = Length of torque wrench (distance between center of drive and center of hand grip).

E = Length of extension of adapter (distance between center of drive and center of broached opening measured in the same place as L).

EXAMPLE: Recommended torque is 100 inch-pounds. Using a 12-inch torque wrench and a 6-inch adapter, determine reading on torque wrench.

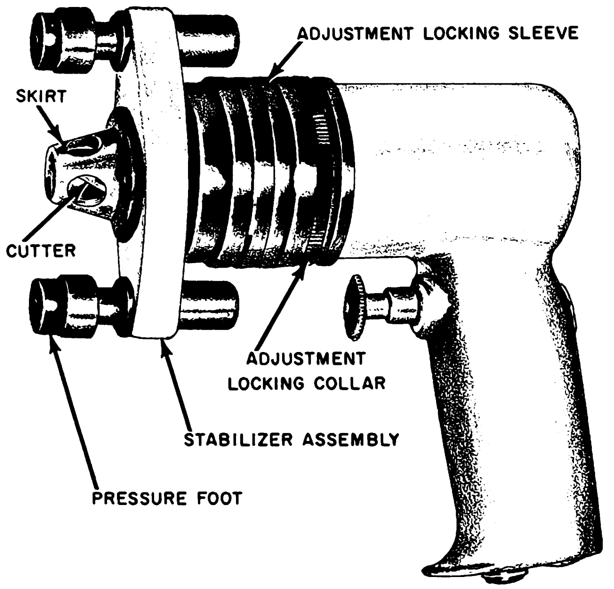
$$S = \frac{100 \times 12}{(6 + 12)} \quad \frac{1200}{18} = 66.6 \text{ inch-pounds}$$

An example of the measuring of this formula is shown in figure 5-9. When the extension is pointed back toward the handle of the torque wrench, subtract the effective length of the extension from the effective length of the torque wrench. If the extension is pointed at a right angle to the torque wrench, then the actual value does not change.

It is not advisable to use a handle extension on a deflecting beam type torque wrench at any time. A handle extension alone has no effect on the reading of other types. The use of a drive and extension on any other type of torque wrench makes the use of the formula mandatory. When applying the formula, force must be applied to the handle of the torque wrench at the point from which the measurements were taken. If this is not done, the torque obtained will be in error.

Rivet Head Shaver

The rivet head shaver shown in figure 5-10 is used by the ASH to smooth countersunk rivet heads that protrude slightly but are still within specified limits. The rivet head shaver is also called a Micro Miller. This unit operates on compressed air. The depth of cut adjustment can be made in increments of 0.0005 inch on the model shown in figure 5-10. On some models the depth of cut adjustment can be mad_ in increments of 0.0008 inch. The operator can change cutters and adjust their depth without the use of special tools. Once the depth is set, the positive action of the serrated adjustment locking collar prevents accidental loss of setting.



AM.305
Figure 5-10.—Rivet head shaver.

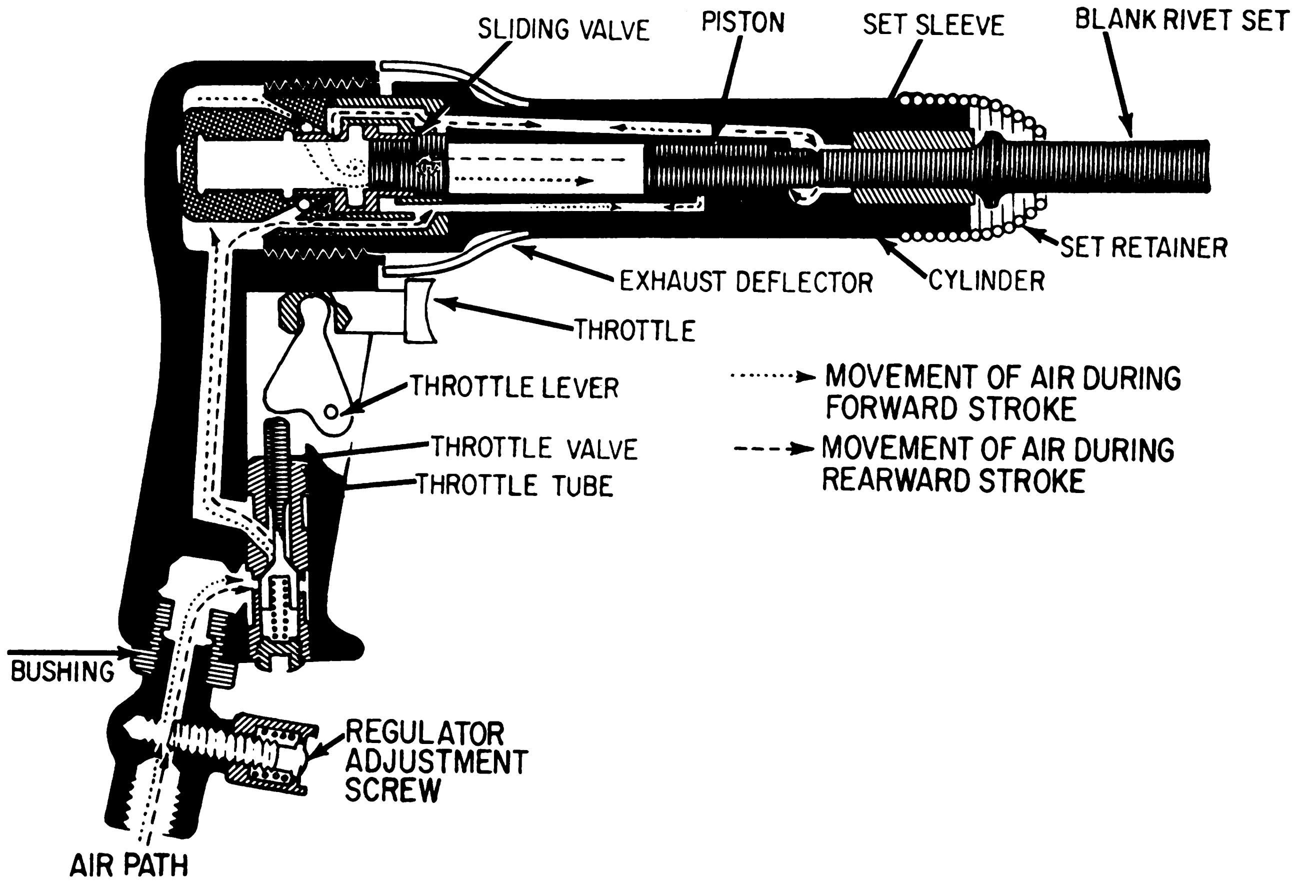
The ASH should position the cutters directly over the rivet head, holding the tool at an angle of 90 degrees to the surface being smoothed.

With the tool turning maximum rpm, it is then pressed in towards the surface, maintaining the 90-degree angle. The pressure feet will then be compressed until they bottom out. At this time, assuming the rivet head shaver is adjusted correctly prior to the shaving operation, the rivet head will be shaved smooth.

Pneumatic Riveters

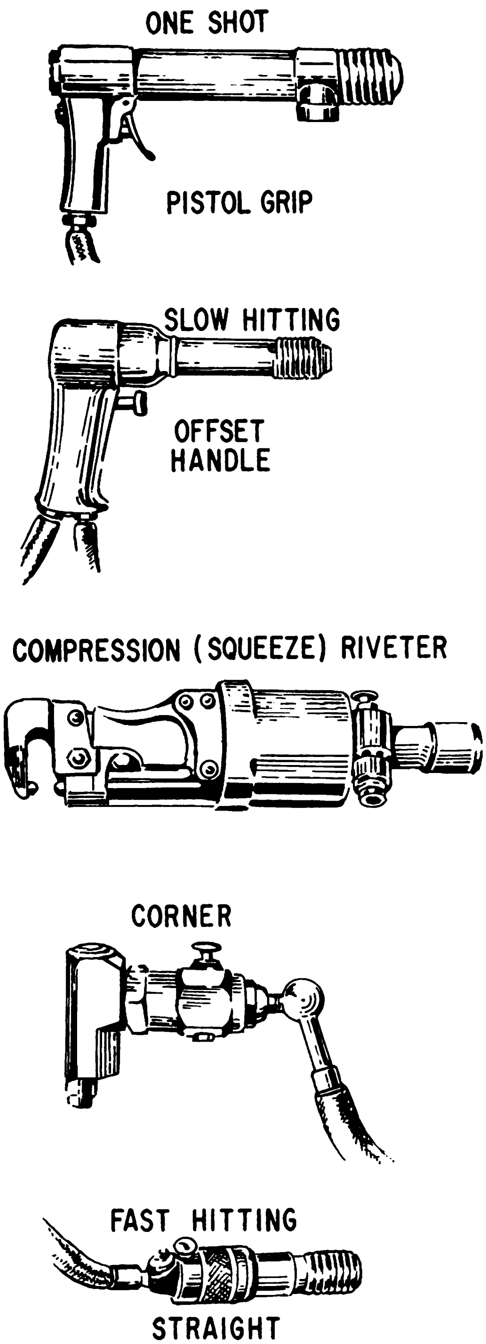
Rivet guns vary in size and shape and have a variety of handles and grips, ranging from the offset type to the pistol grip type. Nearly all riveting is done with penumatic riveters. The pneumatic riveting guns operate on compressed air supplied from a compressor or storage tank. Normally, rivet guns are equipped with an air regulator on the handle to control the amount of air entering the gun. Regulated air entering the gun (fig. 5-11) passes through the handle and throttle valve, which is controlled by the trigger, and into the cylinder in which the piston moves. Air pressure forces the piston down against the rivet set and exhausts itself through side ports. The rivet set recoils, forcing the piston back, and the cycle is repeated. Each time the piston strikes the rivet set, the force is transmitted to the rivet. Rivet sets come in various sizes and shapes to fit the various shaped rivet heads.

Several types of pneumatic riveters are in general use. Included are the one-shot gun, slow-hitting gun, fast-hitting gun, corner riveter, and squeeze riveter. (See fig. 5-12). The type of gun used depends on the particular job at hand, each type having its advantage for



AM.306

Figure 5-11.—Rivet gun internal airflow.



AM.307

Figure 5-12.—Various types of rivet guns.

certain types of work. Small parts can be riveted by one man if the part is accessible for both bucking and driving, provided the work is properly secured. The greatest part of riveted work, however, requires two men. Riveting procedures are discussed in chapter 10 of this training manual.

ONE-SHOT GUN.—The one-shot gun is designed to drive the rivet with just one blow. It is larger and heavier than other types and is generally used for heavy riveting. Each time the trigger is depressed the gun strikes one blow. It is rather difficult to control on light-gage metals. Under suitable conditions it is the fastest method of riveting.

SLOW-HITTING GUN.—The slow-hitting gun has a speed of 2,500 bpm (blows per minute). As long as the trigger is held down, the rivet set continues to strike the rivet. This gun is widely used for driving medium-size rivets. It is easier to control than the one-shot gun.

FAST-HITTING GUN.—The fast-hitting gun heads the rivet with a number of relatively light-weight blows. It strikes between 2,500 and 5,000 bpm and is generally used with softer rivets. Like the slow-hitting gun, it continues to strike the rivet head as long as the trigger is depressed. This gun is sometimes referred to as a vibrator.

CORNER RIVETER.—The corner riveter is so named because it can be used in corners and in close quarters where space is restricted. The main difference between this riveter and the other types described lies in the fact that in this type the set is very short and can be used in confined spaces as can be seen in figure 5-12.

SQUEEZE RIVETER.—The squeeze riveter differs from the other riveters in that it forms the rivet head by means of squeezing or compressing instead of by distinct blows. Once it is adjusted for a particular type of work, it will form rivet heads of greater uniformity than the riveting guns. It is made both as a portable unit and as a stationary riveting machine. As a portable unit, it is larger than the riveting guns and can be used only for certain types of work that can be accommodated between the jaws. The stationary, or fixed jaw, contains the set and is placed against the rivet head in driving. The rivet squeezer illustrated in figure 5-12 is the portable pneumatic unit.

RIVET GUN SELECTION.—The size and the type of gun used for a particular job depend upon the size of rivets being driven and the accessibility of the rivet. For driving medium-size, heat-treated rivets which are in accessible places, the slow-hitting gun is preferred. For small, soft alloy rivets, the fast-hitting gun is

preferable. There will be places where a conventional type gun cannot be used. For this type work, a corner gun is employed.

The larger the rivet, the greater the air pressure that is required. Air pressure reaches the gun through a long, flexible hose. Approximate air pressures for four of the most common rivet sizes are given in table 5-2. Conditions may vary slightly with different metals.

Table 5-2.—Approximate air pressures for rivet guns.

Rivet size	Air pressure psi
3/32	35
1/8	40
5/32	60
3/16	90

HARDWARE

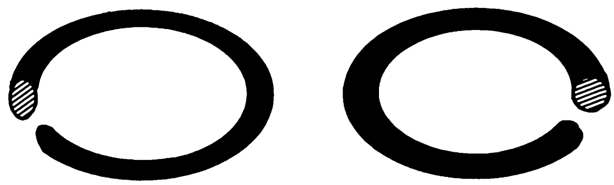
Various types of hardware are used by the ASH in carrying out his assigned tasks. It is necessary for the ASH to be able to select the proper seals, nuts, bolts, rivets, turnlock fasteners, etc. To do this, a basic knowledge of these various items is mandatory. Information such as the type, size, and material of which an item is manufactured is necessary for procurement of the item. Normally, information for ordering the needed materials can be obtained from the applicable Illustrated Parts Breakdown Manual.

SEALS

Seals are used throughout hydraulic and pneumatic systems of ground support equipment to minimize internal and external leakage of fluid, thereby preventing the loss of system pressure. A seal may consist of more than one component, such as an O-ring and a backup ring, or possibly an O-ring and two backup rings. (A backup ring, discussed later in this section, is a leather or Teflon washer used on one or both sides of a seal to allow higher pressure to be applied to the seal. Without backup rings, high pressures will cause a seal to distort to such an extent that it will be forced into the clearance between mating metal parts, resulting in a cut or otherwise damaged seal.) Seals used internally on a sliding or moving assembly are normally called PACKINGS. Seals used between nonmoving fittings and bosses are normally called GASKETS.

Packings and gaskets are manufactured in the form of O-rings, V-rings, U-rings, quad-rings, cup, and various other forms. However, most of those used in ground support equipment are in the form of O-rings. Therefore, the discussion in this section is limited to O-rings. The cup seal is used extensively in brake systems and is discussed in chapter 15.

The O-ring is circular in shape, and its cross section is small in relation to its diameter. The cross section is truly round and is molded and trimmed to extremely close tolerance. An elliptical seal is used in some components. The elliptical seal is similar to the O-ring seal except for its cross-sectional shape. As its name implies, its cross section is elliptical in shape. Both the O-ring and elliptical seals are shown in figure 5-13.



AM.721

Figure 5-13.—O-ring and elliptical seals.

Gaskets

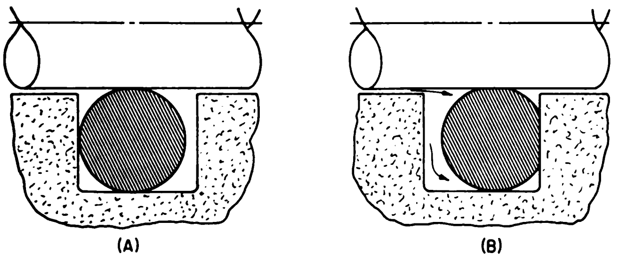
Gaskets are used in the sealing of boss fittings, end caps of actuating cylinders, and other installations where moving parts do not come in contact with the seal. Normally, the type of gasket used is an O-ring. In some cases it may be the same type seal that is used as a packing in other installations, or it may be one which is manufactured only for use as a gasket.

Packings

Most packings used in support equipment installations are made of synthetic rubber.

They are used in units that contain moving parts, such as actuating cylinders, selector valves, etc. As previously mentioned, the O-ring type is most widely used.

The O-ring packing seals effectively in both directions. This sealing is accomplished by distortion of its elastic compound. Figure 5-14 (A) shows an O-ring of the proper size installed in a grooved seat. Notice that the clearance for the O-ring is less than its free outer diameter. The cross section of the O-ring is squeezed out of round prior to the application of pressure. In this manner, contact is insured with the inner and outer walls of the passage under static (no pressure) conditions.

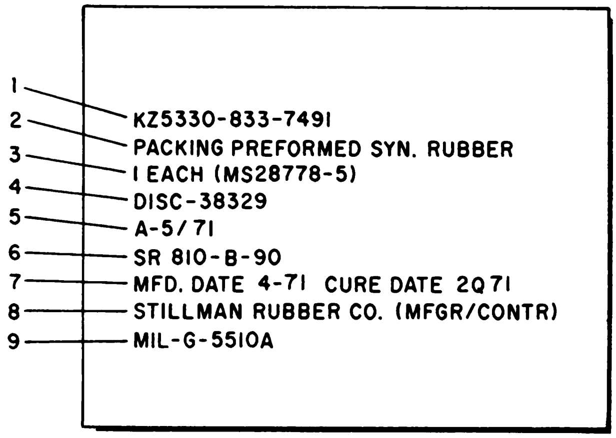


FP.71
Figure 5-14.—O-rings properly installed

Figure 5-14 (B) shows the action of the O-ring when pressure is applied. It should also be noted, in figure 5-14, that backup rings are not installed. In hydraulic systems where components are subjected to 1,500 psi pressure and below, AN6227, AN6230, and MS28775 packings are used. In such installations, backup rings are not required, although desirable. In systems with pressures up to 3,000 psi, backup rings are used in conjunction with the packings.

O-ring Identification

O-rings are manufactured according to Military Specifications and can be best identified from the technical information printed on the O-ring package. (See fig. 5-15.) The size cannot be positively identified by visual examination without the use of special equipment. For this reason, O-rings are made available in individual hermetically sealed envelopes



FP.72
Figure 5-15.—O-ring package identification.

labeled with all the necessary pertinent data. It is recommended that they be procured and stored in these envelopes.

NOTE: Colored dots, dashes, and stripes or combinations of dots and dashes on the surface of the O-ring are no longer used for identification of this type seal.

Figure 5-15 shows the information printed on O-ring packages, essential to determine the intended used, qualifications, and age limitations. The manufacturer's cure date is one of the more important printed items listed on the package. This cure date is denoted in quarters. For example, the cure date 2Q71 indicates that the O-ring was manufactured during the second quarter of 1971. Synthetic rubber parts manufactured during any given quarter are not considered one quarter old until the end of the succeeding quarter. Most O-ring age limitation is determined by this cure date, anticipated service life, and replacement schedule.

Age limitation of synthetic rubber O-rings is based on the fact that the material deteriorates with age. O-ring age is computed from the cure date. The term cure date is used in conjunction with replacement kits which contain O-rings, parts, and hardware for shop repair of various components. O-ring cure dates also provide bases for O-ring replacement schedules, which are determined by O-ring service life. The service life (estimated time

of trouble free service) of O-rings also depends upon such conditions as use, exposure to certain elements, both natural and imposed, and subjection to physical stress. Operational conditions imposed on O-rings in one component may necessitate O-ring replacement more frequently than replacement of identical O-rings in other components. Therefore, it is necessary to adhere to the recommended replacement schedule for each individual component. The age of O-rings in a spare part is determined from the assembly date recorded on the service or identification plate and/or on the exterior of the container. All O-rings over 24 months old should be replaced or, if nearing their age limit (24 months), should not be used for replacement.

O-Ring Storage

Proper storage practices must be observed to prevent deformation and deterioration of rubber O-rings. Most synthetic rubbers are not damaged by several years of storage under ideal conditions. However, most synthetic rubbers deteriorate when exposed to heat, light, oil, grease, fuels, solvents, thinners, moisture, strong drafts, or ozone (form of oxygen formed from electrical discharge). Damage by exposure is magnified when rubber is under tension, compression, or stress. There are several conditions to be avoided, including the following:

1. Deformation as a result of improper stacking of parts and storage containers.
2. Creasing caused by a force applied to corners and edges, and by squeezing between boxes and storage containers.
3. Compression and flattening, as a result of storage under heavy parts.
4. Punctures caused by staples used to attach identification.
5. Deformation and contamination due to hanging the O-rings from nails or pegs. O-rings should be kept in their original envelopes, which provide preservation, protection, identification, and cure date.
6. Contamination by piercing the sealed envelopes to store O-rings on rods, nails, or wire handing devices.
7. Contamination by fluids leaking from parts stored above and adjacent to O-ring surfaces.
8. Contamination caused by adhesive tapes applied directly to O-ring surfaces. A torn O-ring package should be secured with a pressure-sensitive, moisture-proof tape, but the tape must not contact the O-ring surfaces.
9. Retention of overage parts as a result of improper storage arrangement or illegible identification. O-rings should be arranged so the older seals are used first.

O-Ring Removal and Installation

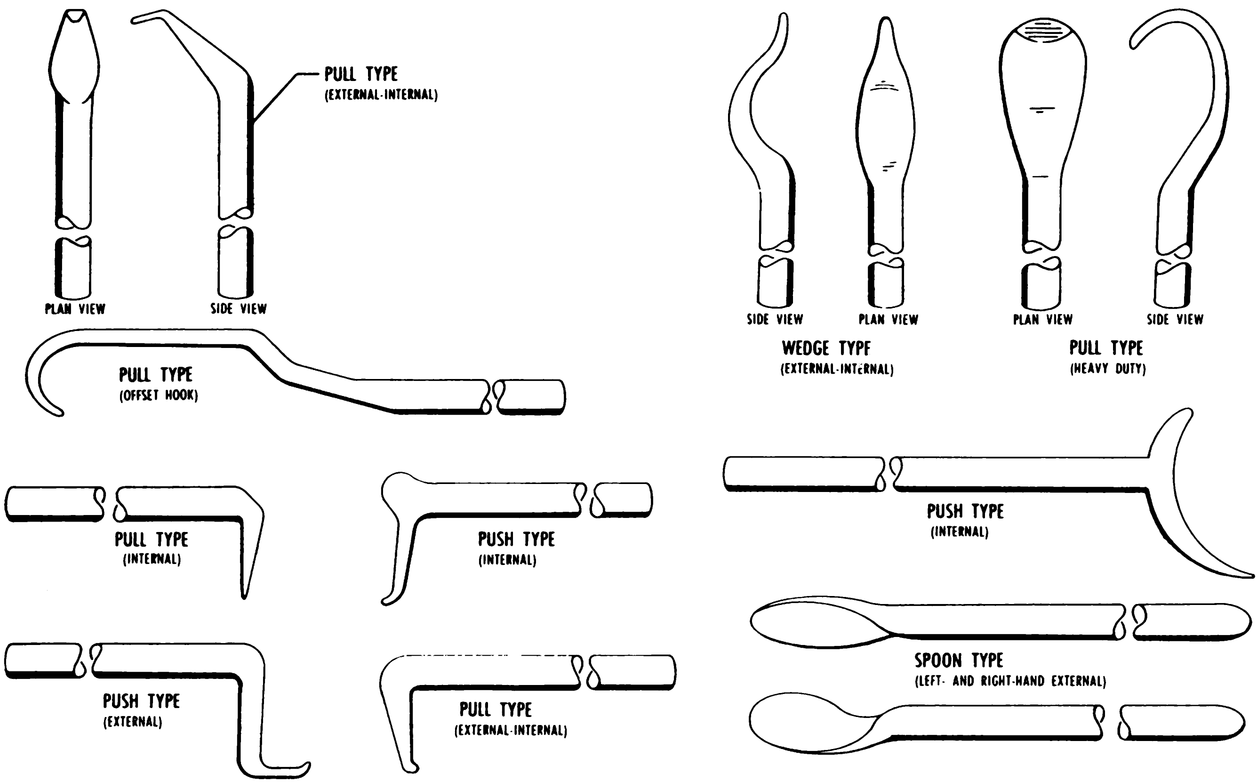
The successful operation of a hydraulic system and the units within depends greatly upon the methods and procedures used in handling and installing hydraulic seals. These seals are comparatively soft and should not be subjected to any nicks, scratches, or dents. They should be kept free of dirt and foreign matter and should not be exposed to extreme weather conditions. When hydraulic seals are chosen for installation, they should not be picked up with sharp instruments, and the preservative should not be removed until they are ready for installation.

During the installation or removal of hydraulic seals, as well as other tasks, an ASH's best friend is the correct tool. A variety of these tools may be used on any given job. Suggestions for fabricating typical tools for use in replacing and installing O-rings and backup rings are shown in figure 5-16. These tools should be fabricated from soft metal such as brass and aluminum; however, tools made from phenolic rod, plastics, and wood may also be used.

When removing or installing O-rings avoid using pointed or sharp-edged tools which might cause scratching or marring of hydraulic component surfaces or cause damage to the O-rings. While using the seal removal and installation tools, contact with cylinder walls, piston heads, and related precision components is not desirable. With practice, the ASH should become proficient in using these tools.

Notice in figure 5-17 (A) how the hook type removal tool is positioned under the O-ring and then lifted to allow the extractor tools, as well as the removal tools, to pull the O-ring from its cavity. View (B) shows the use of another type of extractor tool in the removal of internally installed O-rings.

In view (C), notice the extractor tool positioned under both O-rings at the same time. This method of manipulating the tool positions both O-rings, allowing the hook type removal



AM.722

Figure 5-16.—Typical O-ring installation and removal tools.

tool to extract both O-rings with minimum effort. View (D) shows practically the same removal as view (C), except for the use of a different type of extractor tool.

The removal of external O-rings is less difficult than the removal of internally installed O-rings. Views (E) and (F) illustrate two accepted removal methods. View (E) shows the use of a spoon type extractor, which is positioned under the seal. After the O-ring is dislodged from its cavity, the spoon is held stationary while simultaneously rotating and withdrawing the piston. View (F) installation is similar to view (E), except only one O-ring is installed, and a different type of extractor tool is used. The wedge type extractor tool is inserted beneath the O-ring; the hook type removal tool hooks the O-ring. A slight pull on the latter tool removes the O-ring from its cavity.

After the removal of all O-rings, cleaning of the affected parts which will receive new O-rings is mandatory. Insure that the area used for such installations is clean and free from all contamination. Each O-ring to be replaced should be removed from its sealed package and inspected for defects such as blemishes, abrasions, cuts, or punctures. Although an O-ring may appear perfect at first glance, slight surface flaws may exist. These are often capable of preventing satisfactory O-ring performance under the variable operating pressures of hydraulic systems. O-rings should be rejected for flaws that will affect their performance.

By rolling the ring on an inspection cone or dowel, the inner diameter surface can also be checked for small cracks, particles of foreign matter, and other irregularities that would cause leakage or shorten the life of O-rings. The slight stretching of the ring when it is

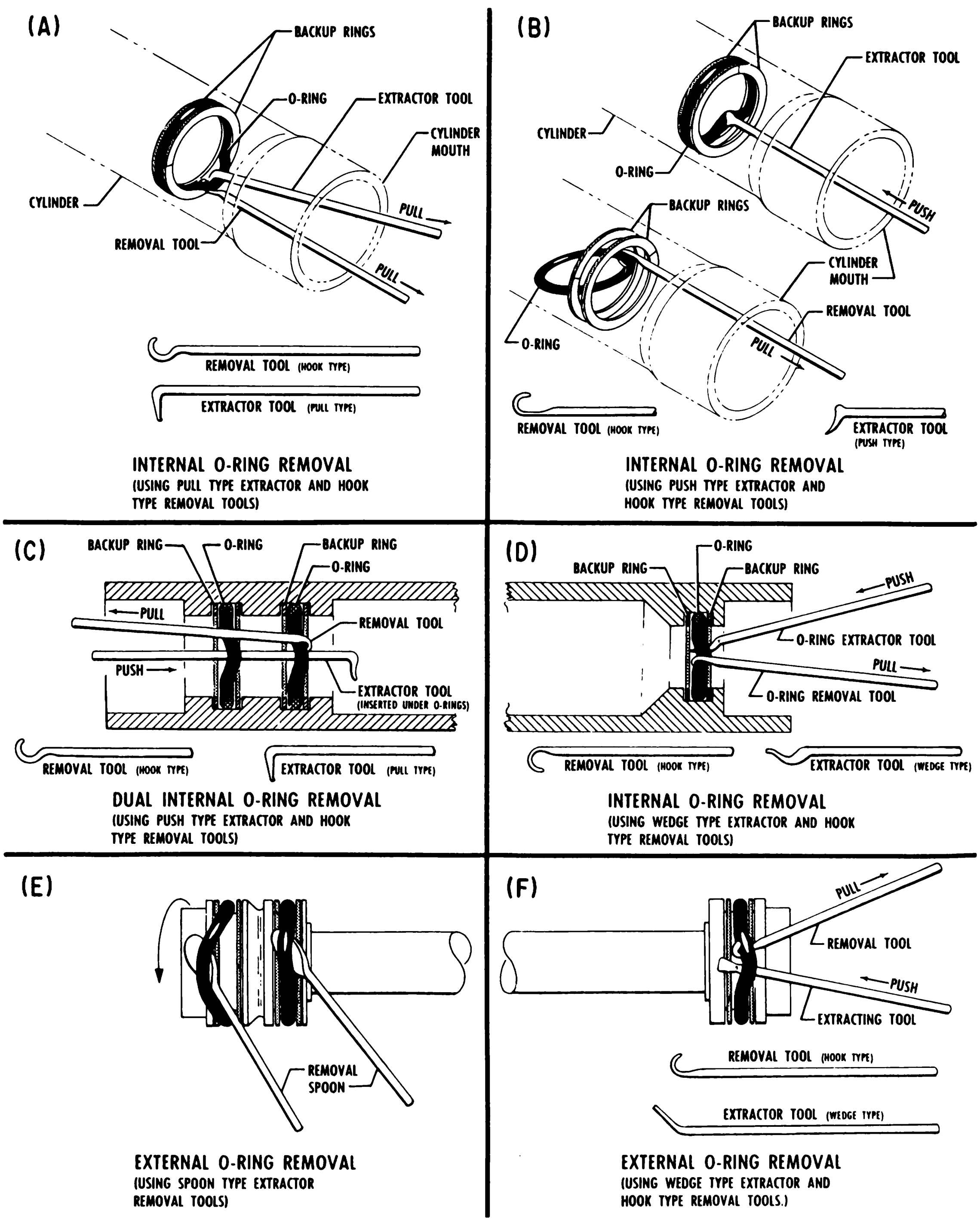


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Figure 5-17.—O-ring removal.

rolled inside out will help to reveal some defects not otherwise visible.

A further check of each O-ring should be made by stretching it between the fingers, but care must be taken not to exceed the elastic limits of the rubber. Following these inspection procedures will prove to be a maintenance economy. It is far more desirable to take care identifying and inspecting O-rings than to repeatedly repair components because of faulty seals.

After inspection and prior to installation, immerse the O-ring in clean hydraulic fluid of the type which is compatible with the seal. During the installation, avoid rolling and twisting the O-ring to maneuver it into place. If possible, keep the position of the O-ring's mold line constant. When the O-ring installation requires spanning or inserting through sharp threaded areas, ridges, slots, and edges, use protective measures, such as O-ring entering sleeves as shown in figure 5-18 (A). If the recommended O-ring entering sleeve (soft thin-wall metallic sleeve) is not available, paper sleeves and covers may be fabricated by using the seal package (gloss side out) or lint free bond paper. (See fig. 5-18 (B) and (C).)

Adhesive tapes should not be used to cover danger areas on components. Gummy substances left by the adhesives are extremely detrimental to hydraulic systems.

After the O-ring is placed in the cavity provided, gently roll the O-ring with the fingers to remove any twist that might have occurred during installation.

Backup Rings

Backup rings are used to support O-rings and to prevent O-ring deformation and resultant leakage. Two types of backup rings are used in support equipment—Teflon (single and double spiral) and chrome-retanned leather. Teflon backup rings are generally used with both packings and gaskets; however, leather backup rings may be used with gasket type seals in systems operating up to 1,500 psi.

Teflon rings are made from a fluorcarbon-resin material which is tough, friction-resistant, and more durable than leather. Precautions similar to those applicable to O-rings must be taken to avert contamination of backup rings and damage to hydraulic components.

Teflon backup rings may be stocked in individual sealed packages similar to those in which O-rings are packed, or several may be installed on a cardboard mandrel.

If unpackaged rings are stored for a long period of time without the use of mandrels, a condition of overlap may develop. In order to eliminate this condition, stack the Teflon rings on a mandrel of a diameter comparable to the desired diameter of the spiral ring. Stack and clamp the rings with their coils flat and parallel. Then place the rings in an oven at a maximum temperature of 350°F for a period of approximately 10 minutes. The rings are then removed and water quenched. NOTE: After this treatment, rings should be stored at room temperature for a period of 48 hours prior to use.

IDENTIFICATION.—Backup rings are not color coded or otherwise marked and must be identified from package labels.

Backup rings made from Teflon do not deteriorate with age, are unaffected by any fluid or vapor, and tolerate temperature extremes in excess of those encountered in high-pressure hydraulic systems. The dash number, which is found on the package, following the specification number, indicates the size and, in some cases, relates directly to the dash number of the O-ring for which the backup ring is dimensionally suited. For example, the single spiral Teflon ring, MS28774-6, is used with MS28775-006 O-ring; and the double spiral Teflon ring, MS28782-1, is used with the AN6227B-1 O-ring.

INSTALLATION.—Care must be taken during the handling and installation of backup rings. If possible, backup rings should be inserted by hand and without the use of sharp tools. Leather backup rings must first be soaked in the recommended fluid to increase their flexibility for ease of installation. For reuse of leather backup rings, they must be inspected to meet the requirements, as shown in figure 5-19. The Teflon backup rings must also be inspected prior to reuse for evidence of compression damage, scratches, cuts, nicks, and fraying conditions, as illustrated in figure 5-20.

To install the leather type backup ring (fig. 5-21), the following steps should be used:

1. Soak new backup ring in clean hydraulic fluid until it is pliable.
2. Immerse the new gasket in the same type of hydraulic fluid as used in the hydraulic system.
3. Examine the fitting groove for roughness that might damage the seal.

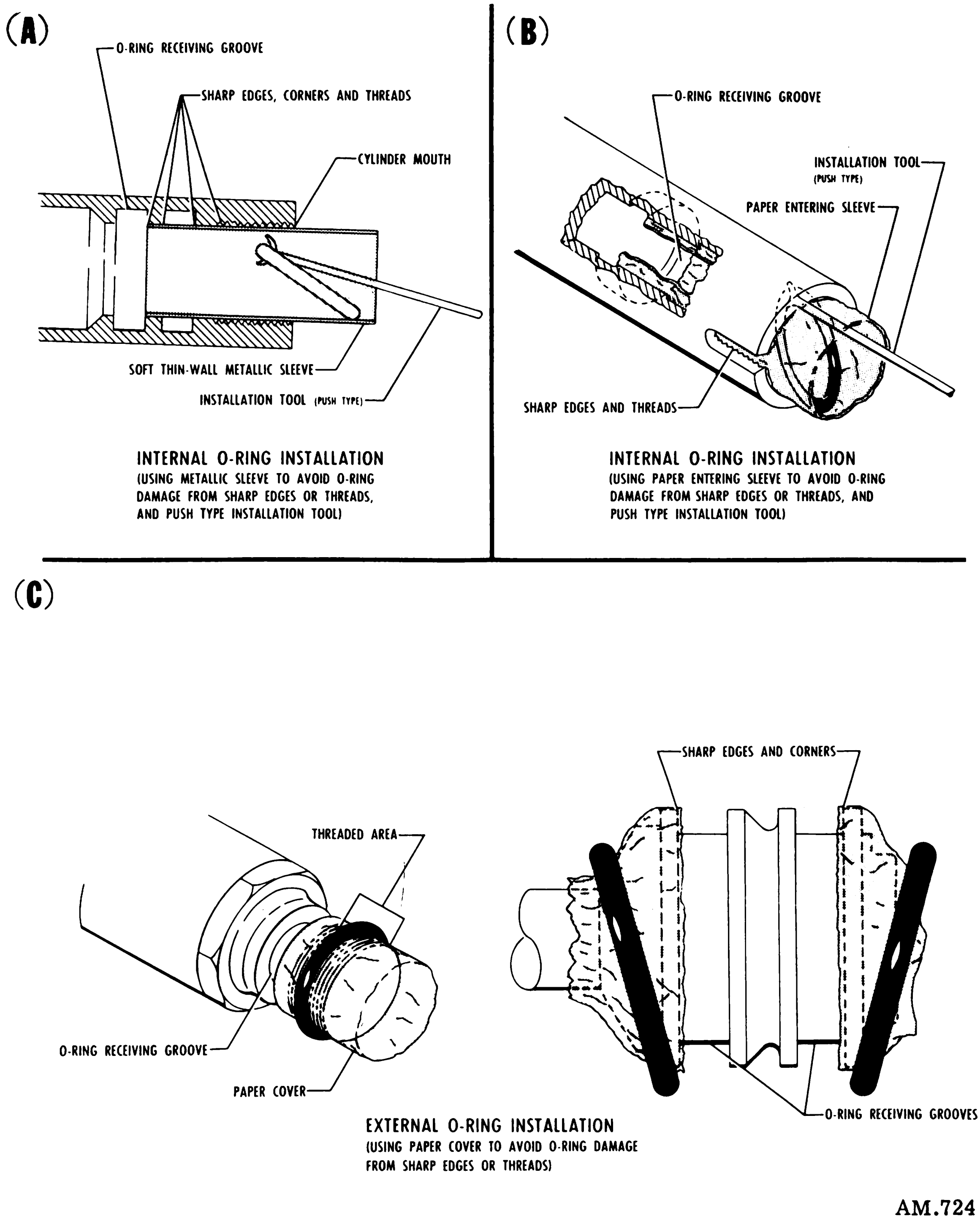

Figure 5-18.—O-ring installation.

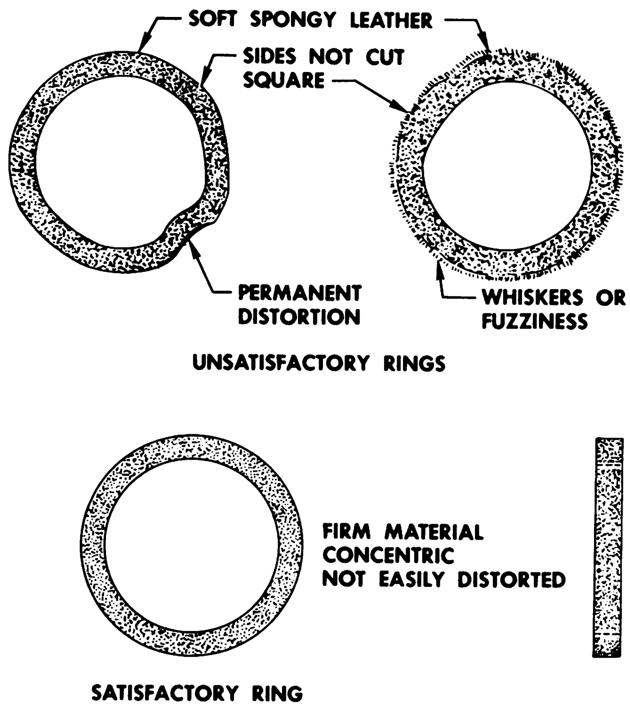

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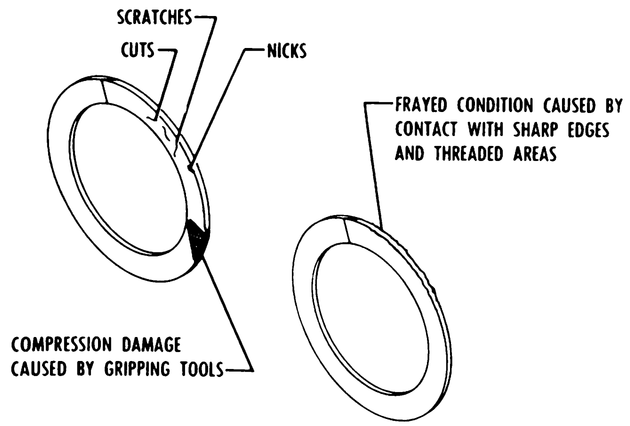
Figure 5-19.—Leather backup rings—satisfactory and unsatisfactory condition.



AM.726
Figure 5-20.—Teflon backup rings—damages caused by improper handling.

4. Position the jamnut well above the fitting groove, and coat the male threads of the fitting sparingly with hydraulic fluid.

5. Install the backup ring in the fitting groove with the smooth side away from the jamnut, and work the backup ring into the counterbore of the jamnut.

6. Install the gasket in the fitting groove against the backup ring.

7. The jamnut is then turned down until the gasket is pushed firmly against the threaded portion of the fitting.

8. Install the fitting into the boss, and turn until the gasket has contacted the boss. (The jamnut must turn with the fitting.)

9. While holding the jamnut from turning, turn the fitting 1 1/2 additional turns.

10. The fitting is then positioned by turning it not more than one turn.

11. Hold the fitting in the desired position, and turn the nut down tight against the boss.

When Teflon spiral rings are being installed in internal grooves, the ring must have a right-hand spiral. Figure 5-22, view (A), shows the method used to change directions of the spiral. The Teflon ring is then stretched slightly, as shown in view (B), prior to installation into its groove. While the Teflon ring is being inserted in the groove, rotate the component in a clockwise direction. This action will tend to expand the ring diameter and reduce the possibility of damage to the ring.

When Teflon spiral rings are being installed in external grooves, the ring should have a left-hand spiral. As the ring is inserted into the groove, rotate the component in a clockwise direction. This action will tend to contract the ring diameter and reduce the possibility of damage to the ring.

Backup rings may be installed singly, if pressure acts only upon one side of the seal. In this case, the backup ring is installed next to the O-ring, opposite the pressure force. (See fig. 5-23 (A).) When dual backup rings are installed, the split scarfed ends must be staggered as shown in view (B). View (C) shows an improper dual ring installation.

Wipers

Wipers (scrapers) are used to clean and lubricate the exposed portion of piston shafts. This prevents foreign matter from entering the system and scoring internal surfaces. They are used in most actuating cylinders. Wipers may be of the metallic (usually copper base alloys) or felt types. In some cases, they are used together, the felt wiper being installed behind the

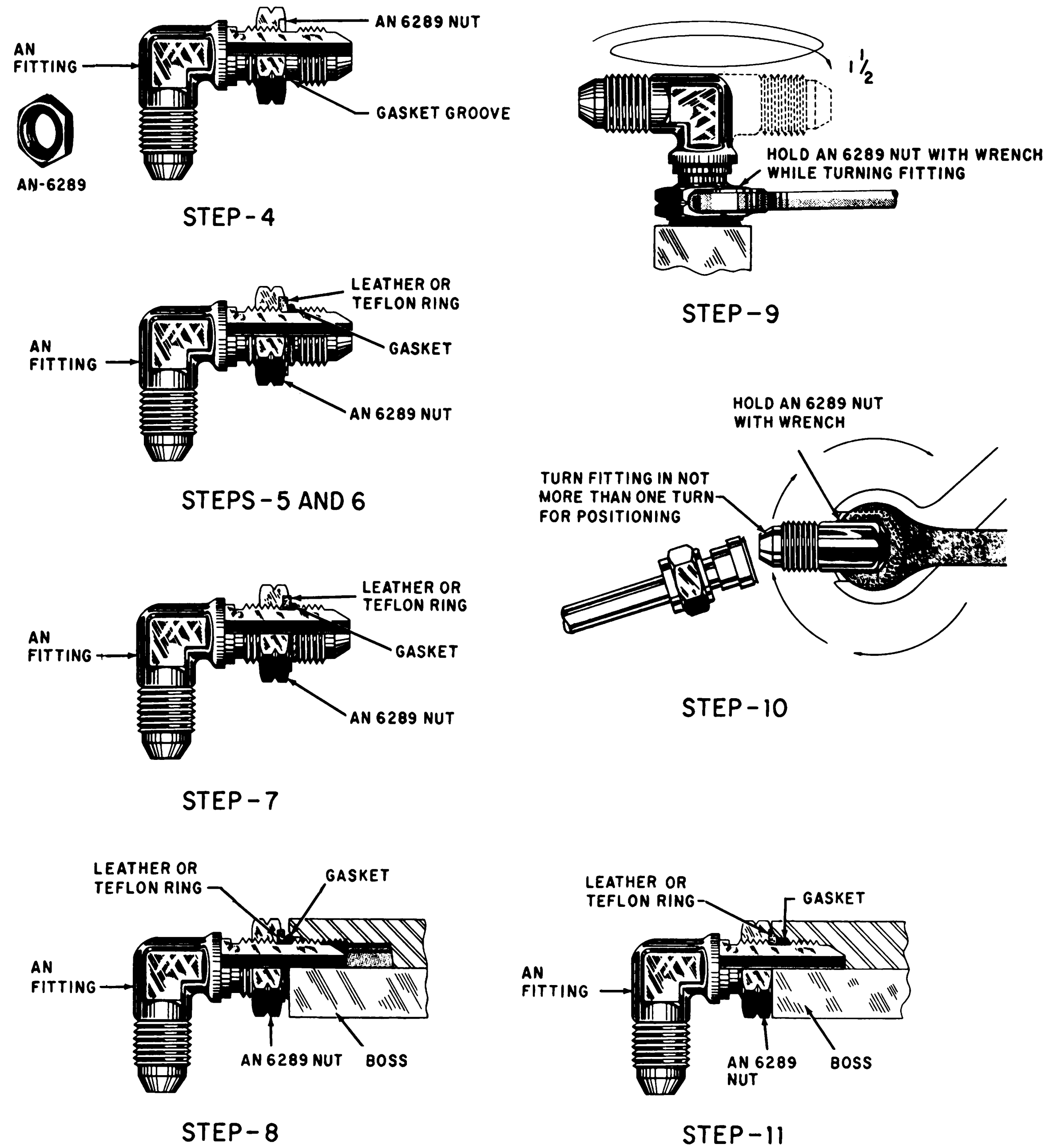


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Figure 5-21.—Properly installed gasket and backup ring.

metallic wiper. Normally, the felt wiper is lubricated with system hydraulic fluid from a drilled bleed passage or from an external fitting.

Wipers are manufactured for a specific hy- hydraulic component and must be ordered for that application. Wipers are normally inspected and changed, if necessary, while component repair is in process.

Metallic wipers are formed in split rings for ease in installation and are manufactured slightly

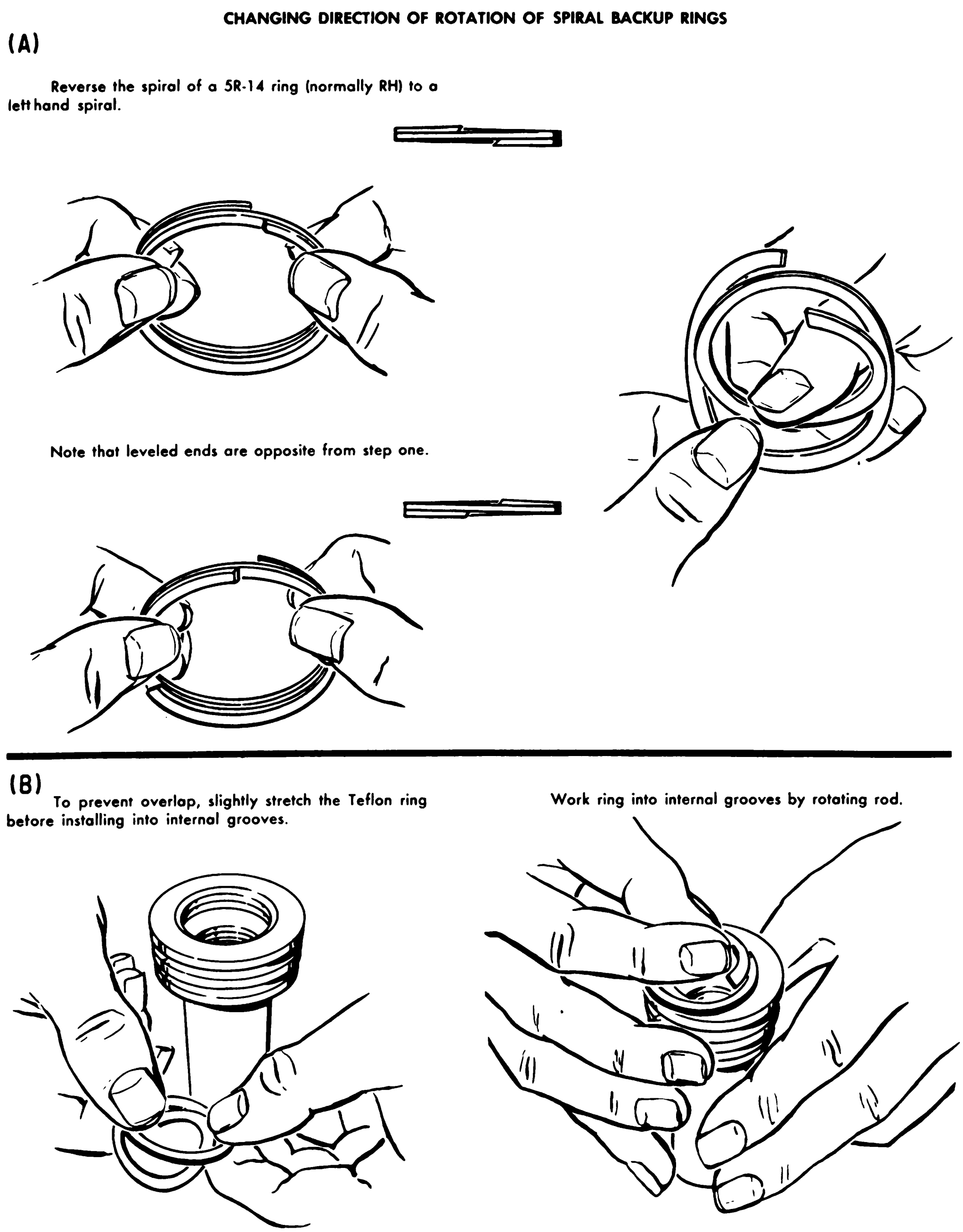

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Figure 5-22.—Installation of Teflon backup rings (internal).

undersize to insure a tight fit. One side of the metallic wiper has a lip which should face outward upon installation. Metallic wipers are inspected for foreign matter and condition and then installed by sliding over the piston shaft in the proper order, as directed by the applicable Instructions Manual.

The felt wiper may be a continuous felt ring or a length of felt with sufficient material to overlap its ends. The felt wiper should be soft,

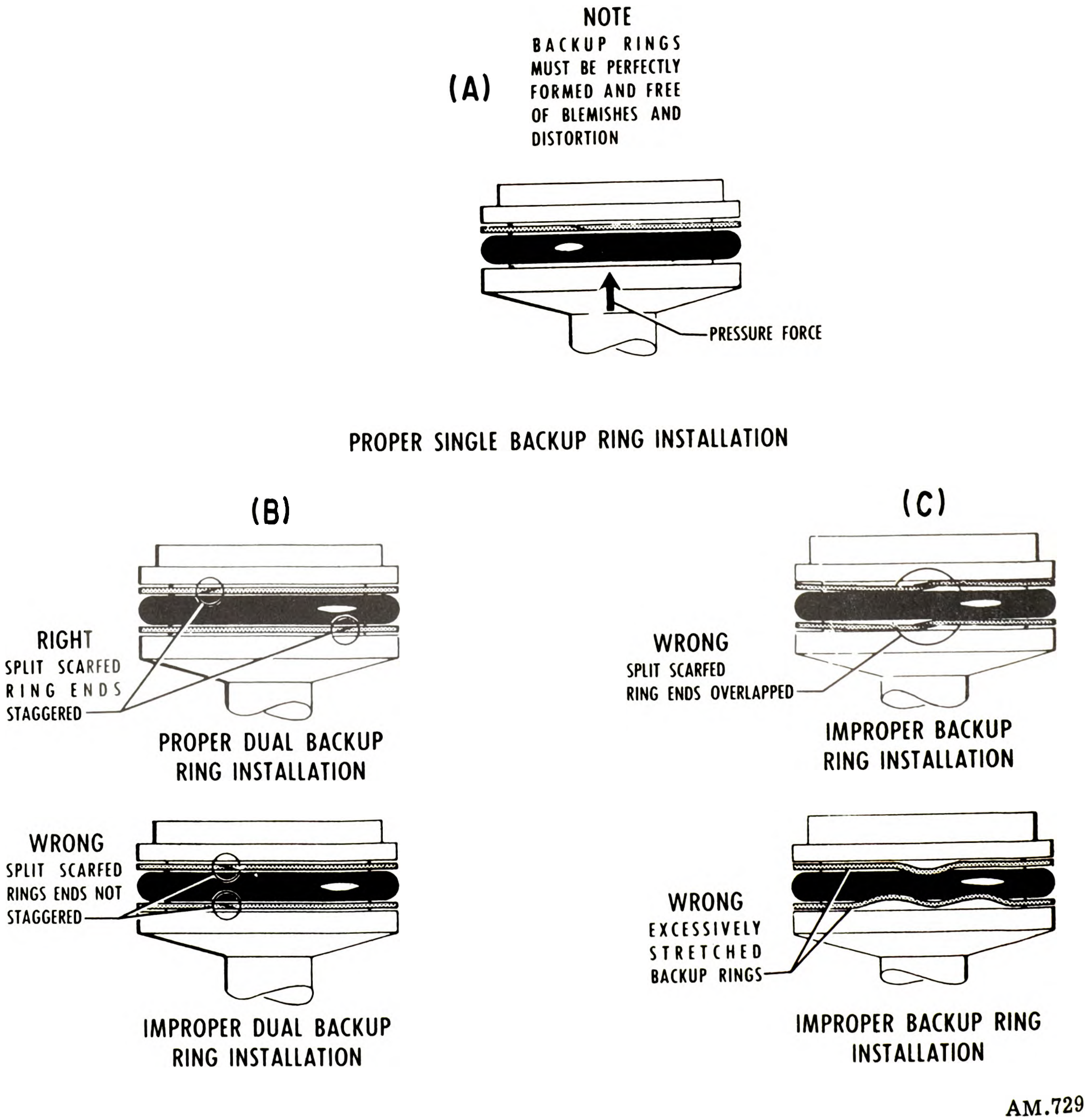

Figure 5-23.—Teflon backup ring installation (external).

clean, and well saturated in hydraulic fluid during installation.

RIVETS

Every ASH should be a skilled riveter. Many of the sheet metal seams on support equipment are joined together with some type of rivet. Rivets are also used for fastening innumerable bracing members and other parts together. Due to the different types of metals and strength requirements of the various types of support equipment, several different types of rivets are required. Rivets that are satisfactory for one area of an item of equipment are often unsatisfactory for another area of the same equipment. It is therefore important that the ASH know the strength and driving properties of the various types of rivets and how to identify them as well as how to drive or otherwise install them. Some of the various rivets used in ground support equipment are described in the following paragraphs. Riveting procedures are covered in chapter 10.

Rivets are available in many different materials, sizes, and types. Rivets made of steel, copper, brass, and aluminum are widely used. In general, rivets should be of the same material as the metal which they join. The two general classifications of rivets used in support equipment are SOLID rivets and BLIND rivets.

Solid Rivets

Solid rivets are classified by their head shape, by the material from which they are manufactured, and by their size. Rivet head shapes and their identification code numbers are shown in figure 5-24. Like the seals described previously, the code numbers of most rivets and, in fact, most hardware are prefixed by the letters MS. The AN rivets shown in the illustration are obsolete for future procurement, but the rivets are allowed to be used until stocks on hand are depleted and replaced with MS rivets.

The various head shapes and their uses are discussed in the following paragraphs.

Roundhead rivets. Roundhead rivets are used in areas where strength is the major factor and streamlining is not important. The size of the head is such that it covers sufficient area to strengthen the sheet around the hole and at the same time offers considerable resistance to tension.

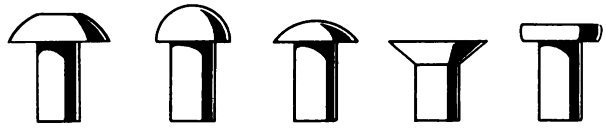

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Figure 5-24.—Rivet head shapes and code numbers.

Flathead rivets. Flathead rivets, like roundhead rivets, are used in the assembly of structures where maximum strength is required, but where interference of nearby members does not permit the use of round head rivets.

Countersunk-head rivets. Countersunk-head rivets, often referred to as FLUSH RIVETS, are used where streamlining is important. For example, practically all external surfaces of pod enclosures for gas turbine power units are flush riveted. Countersunk-head rivets are obtainable with heads having an included angle of 78 and 100 degrees. The 100-degree is the most commonly used type.

Brazier-head rivets. Brazier-head rivets are frequently used on external surfaces of support equipment.

Universal-head rivets. Universal-head rivets are similar to brazier-head rivets and are to be used in place of other protruding head rivets when existing stocks are depleted.

Rivets are also available in various other head types. These include the cone head, round top countersunk head, button head, truss head, and pan head.

RIVET IDENTIFICATION CODE.—The rivet codes as shown in figure 5-24 are sufficient to identify rivets only as to head shape. To be meaningful and to precisely identify a rivet, certain other information is encoded and added to the basic code.

A letter or letters following the head-shape code identifies the material or alloy from which the rivet was made. (Table 5-3 includes a list of the most common of these codes.) The material code is followed by two numbers separated by a dash. The first number is the numerator of a fraction which specifies the shank diameter in thirty-seconds of an inch. The second number is the numerator of a fraction in sixteenths of an inch and identifies the length of the rivet. The rivet code is illustrated in figure 5-25.

Table 5-3.—Rivet material identification.

Material or alloy	Code letters	Head marking on rivet
1100 Aluminum alloy	A	Plain
2117 Aluminum alloy	AD	Indented dimple
2017 Aluminum alloy	D	Raised teat
2024 Aluminum alloy	DD	Raised double dash
5056 Aluminum alloy	B	Raised cross
Corrosion Resistant steel	F	Indented dash
Monel	M	Two raised teats

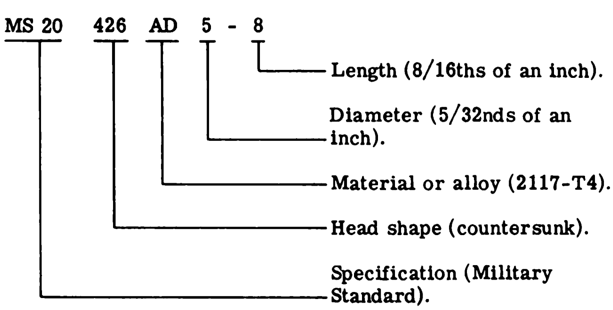

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Figure 5-25.—Rivet coding example.

TINNERS' RIVETS.—Tinners' rivets are often used to fasten some types of sheet metal such as galvanized iron. Tinners' rivets are made from mild steel and have flat heads. These rivets are usually coated with tin or zinc.

Tinners' rivets vary in size from the 8-ounce rivet to the 16-pound rivet. The size designation indicates the weight of 1,000 rivets; thus, if 1,000 rivets weigh 8 ounces, each rivet is called an 8-ounce rivet. As the weight per 1,000 rivets increases, the diameter and length also increase. For example, the 8-ounce rivet has a diameter of 0.089 inch and a length of 5/32 inch, while the 12-pound rivet has a diameter of 0.259 inch and a length of 1/2 inch.

Blind Rivets

There are many places on ground support equipment where access to both sides of a riveted structural part is impossible, or where limited space does not permit the use of a bucking bar. Furthermore, in the attachment of many nonstructural members, the full strength of solid shank rivets is not necessary.

For use in such places, rivets have been designed which can be formed from the outside. They are lighter than solid shank rivets, yet amply strong. These rivets are manufactured by various corporations and have characteristic peculiarities, chief of which is the requirement of special installation tools. Rivets in this category are commonly referred to as blind rivets because of the self-heading feature.

The most common types of blind rivets are the self-plugging (friction lock), the self-plugging (mechanical lock), and the Rivnut. These rivets are adequately described and illustrated in Airman, NavPers 10307 (Series). Furthermore,

installation procedures for these rivets are described in chapter 10 of this manual.

TURNLOCK FASTENERS

Turnlock fasteners are used to secure inspection plates, doors, and other removable panels on some items of support equipment. Turnlock fasteners are also referred to by such terms as quick-opening and quick-action fasteners. The most desirable feature of these fasteners is that they permit quick and easy removal of access panels for inspection and servicing purposes. Removal and replacement of damaged turnlock fasteners is one of the responsibilities of the ASH.

Turnlock fasteners are manufactured and supplied by a number of manufacturers under various trade names. Some of the most commonly used are the Camloc, Airloc, and Dzus (pronounced zoo'-s).

The Camloc and Dzus turnlock fasteners are described and illustrated in Airman, NavPers 10307 (Series). Therefore, only the Airloc fastener is covered in this chapter. The removal, repair, and installation of all three types are discussed in chapter 10.

Airloc Fasteners

Figure 5-26 illustrates the parts that make up an Airloc fastener. As with the Camloc fastener, the Airloc fastener also consists of a receptacle, a stud, and a cross pin. The stud is attached to the access panel and is held in place by the cross pin. The receptacle is riveted to the access panel frame.

Two types of Airloc receptacles are available—the fixed type (insert A of fig. 5-26) and the floating type (insert B of fig. 5-26). The floating type makes for easier alignment of the stud in the receptacle. Several types of studs are also available, but in each instance the stud and cross pin come as separate units so that the stud may be easily installed in the access panel.

The size of Airloc fasteners is indicated by a number and is determined by the distance between the centers of the receptacle rivet holes. The Navy usually uses Nos. 2, 5, and 7, which are 3/4 inch, 1 inch, and 1 3/8 inches, respectively. The diameter of the stud shank and the length of the cross pin vary with the different sizes. The stud is available in round, countersunk, or winged head styles.

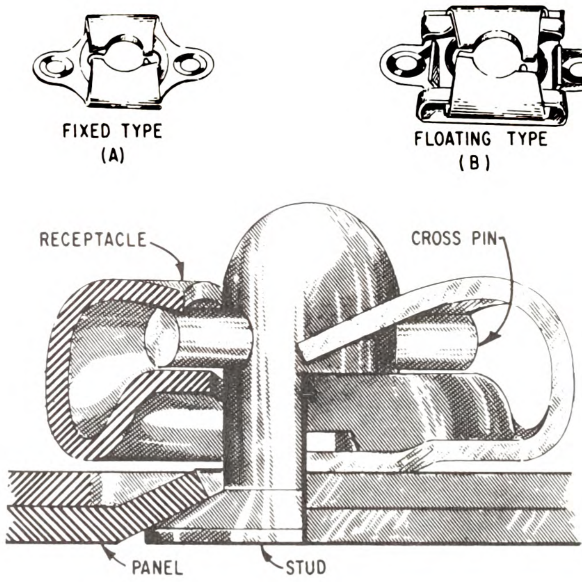

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Figure 5-26.—Airloc fastener.

THREADED FASTENERS

Many different types of threaded fasteners are used in the construction of the various types and models of support equipment. Most of these are standard fasteners; however, special fasteners, designed by the manufacturer, are used in the construction of certain types of equipment. Threaded fasteners include bolts, screws, and nuts.

The most common types of threaded fasteners and washers, including installation procedures, are described and illustrated in Airman, NavPers 10307 (Series). Not included in the Airman Manual is the sheet spring nut which is used on some items of support equipment. This type nut is described in the following paragraph.

The sheet spring nut illustrated in figure 5-27 is sometimes used for anchoring lightweight parts in support equipment. Applications include supporting line clamps, electrical equipment, small access doors, etc. It is made of sheet spring steel, cut so as to have two flaps. The ends of these flaps are notched to form a hole that is somewhat smaller in diameter than the screw used. The sheet spring nut has a

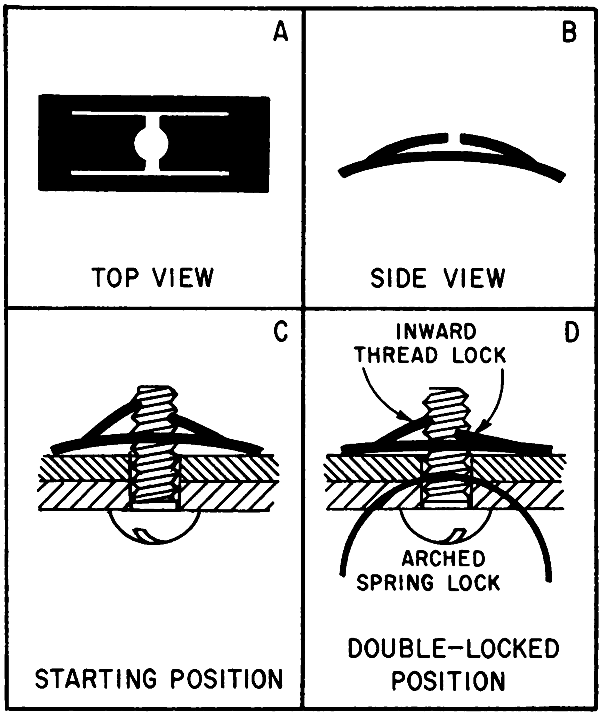

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Figure 5-27.—Sheet spring nut.

definite arch which tends to flatten out as the screw pulls the flaps in toward the threads. This flattening action forces the flaps of the nut tightly into the threads of the screw, and the springiness of the sheet spring nut pushes upward on the screw threads, binding them and locking the screw in place. Either a standard or a sheet-metal self-tapping screw is used with this nut.

SAFETYING MATERIAL

The ASH will come in contact with many different types of safetying materials. These materials are used to stop rotation and other movement of fasteners, and securing of other equipment likely to come loose due to vibration.

Cotter Pins

Cotter pins are used to secure bolts, screws, nuts, and pins. Some cotter pins are made of low-carbon steel, while others consist of stainless steel and thus are more resistant to corrosion. In addition, stainless steel cotter pins may be used in locations where nonmagnetic material is required. Regardless of shape or material, all cotter pins are used for the same general purpose—safetying. Figure 5-28 shows three types of cotter pins and how their size is determined.

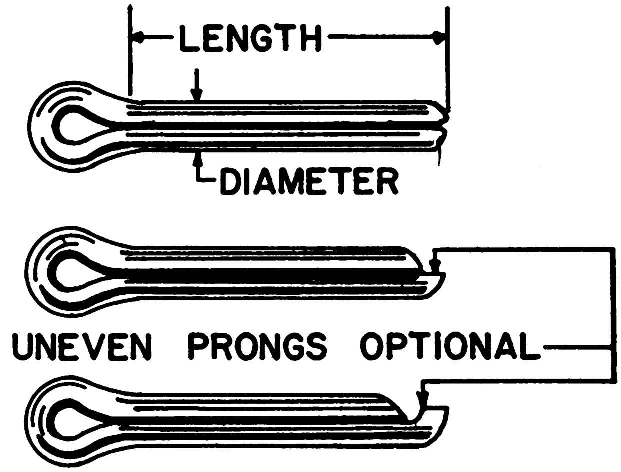

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Figure 5-28.—Types of cotter pins.

NOTE: Whenever uneven prong cotter pins are used, the length measurement is to the end of the shortest prong.

Safety Wire

Safety wire is available in many different types and sizes. One must first select the correct type and size wire for the particular job. Many of the nuts, except the self-locking types, and boltheads on support equipment must be safetied; the method used depending upon the particular installation. Figure 5-29 illustrates the correct methods of installing safety wire. The following general rules apply to safety wiring:

1. All safety wire must be tight after installation, but not under so much tension that normal handling or vibration will break the wire.
2. The wire must be applied so that all pull exerted by the wire tends to tighten the nut or bolt.

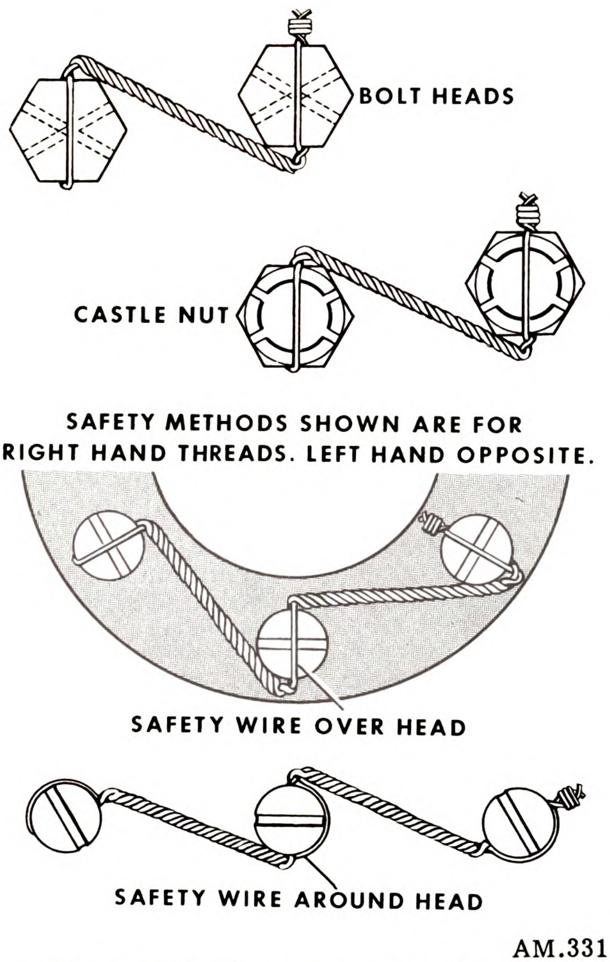

Figure 5-29.—Safety wire installation.

3. Twists should be tight and even and the wire between nuts as taut as possible without overtwisting. Wire-twister pliers should be used if available; otherwise, wire between nuts should be twisted with the hands. The use of regular pliers will damage the wire. Regular pliers may be used only for final end twist prior to cutting off the excess wire.

CHAPTER 6

METAL-WORKING SKILLS

The structural maintenance and repair of ground support equipment is one of the major areas of responsibilities within the scope of the ASH rating. This includes cutting, forming, patching and welding of different types of metals. To accomplish this, the ASH should have a basic knowledge of the properties and characteristics of the different metals used in the construction and repair of ground support equipment. He should also be familiar with the common terms used to identify the properties, characteristics, heat-treating processes, and alloying of metals. These terms are discussed in the first section of this chapter. The remainder of the chapter is devoted to the types and operation of metal-working machines and equipment.

METALS

Each metal has certain qualities which make it desirable for a particular application, but it may have other properties and characteristics that are undesirable. For example, some metals are hard, others comparatively soft; some are brittle, some are tough; some can be formed and shaped without fracture; and some are light in weight, while others are extremely heavy. Metallurgists are continually working to improve the desirable qualities and tone down or eliminate the undesirable ones. This is done by the alloying (combining) of metals and by various heat-treating processes. One does not need to be a metallurgist to be a good ASH, but he should possess a knowledge and understanding of the uses, strengths, limitations, and other characteristics of the metals used in the construction and repair of ground support equipment. Such knowledge and understanding are vital to properly maintain and repair equipment. The selection of the specific material for a specific application demands familiarity with the most common properties of various metals.

PROPERTIES OF METALS

Metals and alloys vary widely in their characteristics and properties. Some of these properties are chemical and involve the behavior of the metal in contact with the atmosphere, salt water, or other substances. Others are electrical, and concern the electrical conductivity, resistance, and magnetic qualities of the metal. There are also physical properties which relate to color, density and weight, and heat conductivity. In addition, there are mechanical properties which relate to load-carrying ability, wear resistance, and elasticity. Of primary concern in the maintenance of support equipment are such general properties as hardness, malleability, ductility, elasticity, toughness, density, brittleness, fusibility, conductivity, contraction and expansion, etc. The ASH should know the definition of these terms as they form the basis for further discussion of metals.

Hardness

Hardness refers to the ability of a metal to resist abrasion, penetration, cutting action, or permanent distortion. Hardness may be increased by working the metal and, in the case of steel and certain aluminum alloys, by heat treatment and cold-working (discussed later). Structural parts are often formed from metals in their soft state and then heat treated to harden them so that the finished shape will be retained. Hardness and strength are closely associated properties of all metals.

Brittleness

Brittleness is the property of a metal which allows little bending or deformation without shattering. In other words, a brittle metal is apt to break or crack without change of shape. Structural members of support equipment are often subjected to shock loads. Therefore, brittleness is not a desirable property. Cast iron, cast aluminum, and very hard steel are brittle metals.

Malleability

A metal which can be hammered, rolled, or pressed into various shapes without cracking

or breaking or other detrimental effects, is said to be malleable. This property is necessary in sheet metal which is to be worked into curved shapes such as fenders, hoods, and pod enclosures.

Ductility

Ductility is that property of a metal which permits it to be permanently drawn, bent, or twisted into various shapes without breaking. This property is essential for metals used in making wire and tubing. Ductility is similar to malleability.

Elasticity

Elasticity is that property which enables a metal to return to its original shape when the force which causes the change of shape is removed. This property is extremely valuable, because it would be undesirable to have a part permanently distorted after an applied load was removed. Each metal has a point known as the ELASTIC LIMIT beyond which it cannot be loaded without causing permanent distortion. When metal is loaded beyond its elastic limit and permanent distortion does result, it is said to have been STRAINED. In the construction of equipment, members and parts are so designed that the maximum loads to which they are subjected will never stress them beyond their elastic limit. (NOTE: STRESS is the internal resistance of any metal to distortion.) This desirable property (elasticity) is present to a high degree in metals used for making springs.

Toughness

Toughness is that property of a metal which enables it to withstand shock without breaking or being deformed. It is thus related to strength and to ductility. Usually as the hardness of a metal increases the toughness decreases.

Fusibility

Fusibility is defined as the ability of a metal to become liquid by the application of heat. Metals are fused in welding. Steel fuses around 2,500° Fahrenheit (F) and aluminum alloys at approximately 1,110° F.

Conductivity

Conductivity is the property which enables a metal to carry heat or electricity. The heat conductivity of a metal is especially important in welding, because it governs the amount of heat that is required for proper fusion. Conductivity of the metal, to a certain extent, determines the type of jig to be used to control expansion and contraction. Metals vary in their capacity to conduct heat. Copper, for example, has a relatively high rate of heat conductivity and is a good electrical conductor.

Expansion and Contraction

Expansion and contraction are reactions produced in metals as the result of heating or cooling. A high degree of heat applied to a metal will cause it to expand or become larger. Cooling hot metal will shrink or contract it. Expansion and construction affect the design of welding jigs, castings, and tolerances necessary for hot-rolled metals.

QUALITIES OF METALS

The selection of proper materials is a primary consideration in the construction and repair of ground support equipment. Keeping in mind the general properties of metals, it is now possible to consider the specific requirements which metals must possess to be suitable for support equipment.

Strength and reliability are the main factors which determine the requirements to be met by most of the material used in the construction and repair of support equipment. Although not as critical as in the construction of aircraft, weight is also a factor that must be considered. For example, it is desirable and, to a certain extent, necessary that equipment such as tow bars, workstands, wheel chocks, and pod enclosures be light in weight. In other equipment, such as tow tractors, heavier metals are used to provide extra weight for better traction. All metals, in addition to having a good strength-to-weight ratio, must be reliable, thus minimizing the possibilities of unexpected failures. In addition to these general qualities, the metals selected for definite applications must possess specific qualities suitable for the purpose.

In determining the most suitable material for a particular application, the following qualities must be considered.

Strength

The material must possess the strength required by the demands of dimension, weight,

and use. There are five basic stresses which metals may be required to withstand. These are tension, compression, shear, bending, and torsion. Each is examined separately in the following paragraphs.

TENSION.—The tensile strength of a material is its resistance to a force which tends to pull it apart. Tensile strength is measured in pounds per square inch (psi) and is calculated by dividing the load, in pounds, required to pull the material apart by its cross-sectional area, in square inches. Metal being pulled is under tension.

COMPRESSION.—Compression is the opposite of tension. The compressive strength of a material is its resistance to a crushing force which is the opposite of tensile strength. Compressive strength is also measured in psi.

SHEAR.—Shear is the tendency on the part of parallel members to slide in opposite directions. It is like placing a cord or thread between the blades of a pair of scissors. In fact, that is how shears got their name. When a piece of metal is being cut with shears, the material is subject (as it comes in contact with the cutting edges) to shear. The shear strength is the shear force in pounds per square inch at which a material fails. It is the load divided by the shear area.

BENDING.—Bending may be described as the deflection or curving of a member due to forces acting upon it. The bending strength of material is the resistance it offers to deflecting forces.

TORSION.—Torsion is a twisting force. Such action would occur in a member fixed at one end and twisted at the other. The torsion strength of material is its resistance to twisting.

Weight

The relationship between the strength of a material and its weight per cubic inch, expressed as a ratio, is known as the STRENGTH/WEIGHT RATIO. This ratio forms the basis of comparing the desirability of various metals used in the construction and repair of ground support equipment. Neither strength nor weight alone can be used as a means of true comparison. In some applications, thickness is more important than strength; and in this instance, the material with the lightest weight for a given thickness is best. Thickness or bulk is necessary to prevent buckling or damage caused by careless handling.

Corrosive Properties

Corrosion is the eating away or pitting of the surface or the internal structure of metals. Ground support equipment is normally used and stored in the open. The equipment may be located in many different geographical areas, afloat or ashore, exposing it to various climatic and atmospheric conditions. Many of these conditions contribute to the corrosion process. Therefore, it would be undesirable and, in some instances, dangerous to select metals subject to severe corrosion if it were not possible to reduce or eliminate the hazard. Corrosion can be reduced or prevented by using better grades of base metals; coating the surfaces with a thin coating of paint, tin, chromium or cadmium; or by an electrochemical process, called anodizing. Corrosion and its control are discussed in detail in chapter 17.

Working Properties

Another significant factor to consider in the selection of metals for maintenance and repair is the ability of material to be formed, bent, or machined to the required shapes. The hardening of metals by cold-working or forming is termed WORK HARDENING. If a piece of metal is formed (shaped or bent) while cold, it is said to be cold-worked. Practically all the work an ASH does on metal is cold-work. While this is convenient, it causes the metal to become harder and more brittle.

If the metal is cold-worked too much (that is, if it is bent back and forth or hammered at the same place too often), it will crack or break. Usually, the more malleable and ductile a metal is, the more cold-working it can withstand.

Joining Properties

Joining metals structurally by welding, brazing, or soldering, or by such mechanical means as riveting or bolting, is a tremendous help in design and fabrication. When all other properties are equal, material that can be welded has the advantage. Welding is discussed in chapters 7, 8, and 9.

Shock and Fatigue Properties

Many of the structural members of support equipment are subject to both shock and fatigue (vibrational) stresses. Fatigue occurs in materials which are exposed to frequent reversals of loading or repeatedly applied loads,

if the fatigue limit is reached or exceeded. Repeated vibration or bending will ultimately cause a minute crack to occur at the weakest point. As vibration or bending continues, the crack lengthens until complete failure of the part results. This is termed shock and fatigue failure. Resistance to this condition is known as shock and fatigue resistance. It is essential that materials used for critical parts be resistant to these stresses.

The preceding discussion on the properties and qualities of metals is intended to show why the ASH must know which traits in metals are desirable and which are undesirable to do certain jobs. The more one knows about a given material, the better able he is to handle it intelligently in the repair of ground support equipment.

METAL-WORKING PROCESSES

When metal is not cast in a desired manner, it is formed into special shapes by mechanical working processes. Several factors must be considered when determining whether a desired shape is to be cast or formed by mechanical working. If the shape is very complicated, casting will be necessary in order to avoid expensive machining of mechanically formed parts. On the other hand, if strength and quality of material are the prime factors in a given part, a casting will be unsatisfactory.

The majority of the structural repairs to be performed by the ASH will involve metals that have been mechanically worked. There are three basic methods of metal working—cold-working, hot-working, and extruding. Mechanical working improves certain properties of the metal. Cold-working, in particular, tends to improve strength and hardness and to produce a smooth surface. Hot-working improves strength and toughness. The process chosen for a particular application depends upon the metal involved and the part required, although in some instances one might employ both hot- and cold-working methods in making a single part. Some of the terms used in connection with mechanical working of metals are given in the following paragraphs.

Hot-Working

Almost all steel is hot-worked from the ingot into some form from which it is either hot- or cold-worked to the finished shape. When an ingot is stripped from its mold, its surface is solid, but the interior is still molten. The ingot is then placed in a soaking pit which retards loss of heat, and the molten interior gradually solidifies. After soaking, the temperature is equalized throughout the ingot, which is then reduced to intermediate size by rolling, making it more readily handled.

The rolled shape is called a bloom when its sectional dimensions are 6 x 6 inches or longer, and approximately square. The section is called a billet when it is approximately square and less than 6 x 6 inches. Rectangular sections which have width greater than twice the thickness are called slabs. The slab is the intermediate shape from which sheets are rolled.

HOT-ROLLING.—Blooms, billets, or slabs are heated above the critical range and rolled into a variety of shapes of uniform cross section. The more common of these rolled shapes are sheet, bar, channels, angles, I-beams, and the like. As discussed later in this chapter, hot-rolled materials are frequently finished by cold-rolling or drawing to obtain accurate finish dimensions and a bright, smooth surface.

FORGING.—Complicated sections which cannot be rolled, or sections of which only a small quantity is required, are usually forged. Forging of steel is a mechanical working of metal above the critical range to shape the metal as desired. Forging is done either by pressing or hammering the heated steel until the desired shape is obtained.

Pressing is used when the parts to be forged are larger and heavy, and this process also replaces hammering where high-grade steel is required. Since a press is slow acting, its force is uniformly transmitted to the center of the section, thus affecting the interior grain structure as well as the exterior to give the best possible structure throughout.

Hammering can be used only on relatively small pieces. Since hammering transmits its force almost instantly, its effect is limited to a small depth. Thus, it is necessary to use a very heavy hammer or to subject the part to repeated blows to insure complete working of the section. If the force applied is too weak to reach the center, the finished forging surface will be concave. If the center is properly worked, the surface will be convex or bulged. The advantage of hammering is that the operator has control over the amount of pressure applied and the finishing temperature, and is able to produce parts of the highest grade.

This type of forging is usually referred to as smith forging and is used extensively where only a small number of parts are needed. Considerable machining and material are saved when a part is smith forged to approximately the finished shape.

Cold-Working

Cold-working applies to mechanical working performed at temperatures below the critical range and results in a strain hardening of the metal. In fact, it becomes so hard that it is difficult to continue the forming process without softening the metal by annealing. Annealing is discussed later in this chapter.

Since the errors attending shrinkage are eliminated in cold-working, a much more compact and better metal is obtained. The strength and hardness, as well as the elastic limit, are increased, but the ductility decreases. Since this makes the metal more brittle, it must be heated from time to time during certain operations to remove the undesirable effects of the working.

COLD-ROLLING.—Cold-rolling usually refers to the working of metal at room temperature. In this operation, the materials that have been hot-rolled to approximate sized are pickled to remove any scale, after which they are passed through chilled finishing rolls. This gives a smooth surface and also brings the pieces to accurate dimensions. The principal forms of cold-rolled stocks are sheets, bars, and rods.

COLD-DRAWING.—Cold-drawing is used in making seamless tubing, wire, and other forms of stock. Wire is made from hot-rolled rods of various diameters. These rods are pickled in acid to remove scale, dipped in lime water, and then dried in a steamroom where they remain until ready for drawing. The lime coating adhering to the metal serves as a lubricant during drawing operation.

The size of the rod used for drawing depends upon the diameter wanted in the finished wire. To reduce the rod to the desired wire size, it is drawn cold through a die. One end of the rod is filed or hammered to a point and slipped through the die opening, where it is gripped by the jaws of the draw, then pulled through the die. This series of operations is done by a mechanism known as the drawbench.

In order to reduce the rod gradually to the desired size, it is necessary to draw the wire through successively smaller dies. Because each of these drawings reduces the ductility of the wire, it must be annealed from time to time before further drawings can be accomplished. Although cold-working reduces ductility, it increases the tensile strength of the wire enormously.

In making seamless steel tubing, the tubing is cold-drawn through a ring-shaped die with a mandrel or metal bar inside the tubing to support it while the drawing operations are being performed. This forces the metal to flow between the die and the mandrel and affords a means of controlling the wall thickness and the inside and outside diameters.

Extruding

The extrusion process involves the forcing of metal through an opening in a die, thus causing the metal to take the shape of the opening. Some metals such as lead, tin, and aluminum may be extruded cold; but generally, metals are heated before the operation is begun.

The principal advantage of the extrusion process is in its flexibility. Aluminum, because of its workability and other favorable properties, can be economically extruded to more intricate shapes and larger sizes than is practicable with many other metals. Extruded shapes are produced in very simple as well as extremely complex sections.

A cylinder of aluminum, for instance, is heated to 750° to 850°F and is then forced through the opening of a die by a hydraulic ram. Many structural parts are formed by the extrusion process.

HEAT TREATMENT

Heat treatment is a series of operations involving the controlled heating and cooling of a metal in its solid state. Heat treating is for the purpose of obtaining or restoring certain desired characteristics or conditions so that the metal will be more suitable for a specific use. By heat treating, a metal may be made harder, stronger, and more resistant to impact. Heat treating can also make a metal softer and more ductile. No one heat-treating operation can produce all of these characteristics. In fact, some properties are often improved at the expense of others. For example, in being hardened, a metal may become brittle.

All of the heat-treating processes are similar in that they involve three steps—heating the

metal to a specific temperature, holding or soaking it at the specific temperature for a definite period, and cooling. They differ, however, in the temperatures to which the metal is heated, the time at temperature, the rate at which it is cooled, and, of course, the final result.

The most common forms of heat treatment for ferrous metals (metals containing an iron base) are hardening, tempering, normalizing, annealing, and casehardening. Most nonferrous metals (aluminum, copper, etc.) can be annealed, and many of them can be hardened by heat treatment. An ASH should have a general understanding of the following heat-treating terms, definitions, and processes.

ANNEALING is a heat-treating process in which a metal is heated to a temperature above its recrystallization point and then cooled slowly. Its purpose may be to induce softness, alter ductility, or refine the grain size of the metal. During annealing, the metal is usually cooled in a furnace or is packed in insulating material, such as dry sand, ashes, or lime, to retard cooling.

CASEHARDENING is a heat-treating operation in which the surface of the metal is made hard and wear resistant while the interior remains relatively soft and tough. In this operation, the surface of the metal is altered in composition by adding carbon, nitrogen, or a combination of both. Casehardening applies only to ferrous metals.

CRITICAL TEMPERATURE RANGE is the temperature at which a ferrous metal undergoes a change in internal structure while being heated or cooled (also called transformation range).

NORMALIZING is similar to annealing but is done for somewhat different purposes. Normalizing is done chiefly to relieve stresses that have been caused by welding, forging, or uneven cooling; to refine the grain structure of the metal before it is hardened; or to harden the metal slightly. In normalizing, the metal is heated to a specified temperature and then allowed to cool in a uniform manner in still air.

PRECIPITATION HEAT TREATMENT is an aging treatment for nonferrous alloys, usually performed at room or slightly elevated temperatures. Certain aluminum alloys are given this treatment following the solution heat treatment.

QUENCHING is the cooling of a metal from a relatively high temperature by immersing it in a cooling medium. The cooling medium may be water, oil, or air.

RECRYSTALLIZATION POINT is the temperature at which the grains in a metal recrystallize or re-form into very small crystals.

SOAKING refers to holding a metal at a required temperature for a specified time to obtain an even temperature throughout the section.

SOLUTION HEAT TREATMENT is a heat treatment for nonferrous alloys in which the alloy is heated to a specified temperature for the required length of time, and is then quenched. The purpose of this treatment is to cause as much of the alloying constituents as possible to go into solid solution and to retain this condition by quenching.

TEMPER DESIGNATION is a term which refers specifically to nonferrous alloys. It consists of letters or letters and numbers which show the condition of the alloy and the heat treatment it has had. The temper designation is usually printed on the surface of the metal.

TEMPERING is the heat-treating operation in which hardened steel is partially annealed and the desired mechanical properties induced by reheating the metal to a temperature below its critical range.

ALLOYING OF METALS

A substance that possesses metallic properties and is composed of two or more chemical elements, of which at least one is a metal, is called an ALLOY. The metal present in the alloy in the largest proportion is called the BASE METAL. All other metals and/or elements added to the alloy are called ALLOYING ELEMENTS. The metals are dissolved in each other while molten, and they do not separate into layers when the solution solidifies.

Alloying elements, either in small or in large amounts, may result in a marked change in the properties of the base metal. For example, pure aluminum is a relatively soft and weak metal, but by adding small amounts of other elements such as copper, manganese, magnesium, zinc, and the like, its strength can be increased many times. Aluminum containing such other elements purposely added during manufacture is called an aluminum alloy.

In addition to increasing the strength, alloying may change the heat-resistant qualities of a metal, its corrosion resistance, electrical conductivity, or magnetic properties. It may cause an increase in the degree to which hardening occurs after cold-working. Alloying may also

make possible an increase or decrease in strength and hardness by heat treatment.

Table 6-1 lists some of the common base metals and alloying elements, and gives the chemical symbol that is used to identify each element.

Table 6-1.—Symbols of base metals and alloying elements.

Element	Symbol
Aluminum	Al
Antimony	Sb
Cadmium	Cd
Carbon	C
Chromium	Cr
Cobalt	Co
Copper	Cu
Iron	Fe
Lead	Pb
Magnesium	Mg
Manganese	Mn
Molybdenum	Mo
Nickel	Ni
Phosphorus	P
Silicon	Si
Sulfur	S
Tin	Sn
Titanium	Ti
Tungsten	W
Vanadium	V
Zinc	Zn

FERROUS METALS

A wide variety of materials is required in the repair of ground support equipment. This is a result of the varying needs with respect to strength, weight, durability, and resistance to deterioration of specific structures or parts. In addition, the particular shape or form of the material plays an important role. In selecting materials for repair, these factors plus many others are considered in relation to their mechanical and physical properties. Among the common materials used are ferrous metals. The term FERROUS applies to the group of metals having iron as their principal constituent.

Ferrous metals include all forms of iron and steel. A few examples of ferrous metals include pig iron, cast iron, ingot iron, and wrought iron. Carbon steel and the various alloy steels—structural as well as tool steel—are also considered as ferrous metals, since they are composed of iron to which relatively small percentages of carbon and other elements have been added as alloying elements.

Iron

Pig iron is composed of about 93 percent iron, from 3 to 5 percent carbon, and varying amounts of other elements. It is comparatively weak and brittle, and has a limited use. About 90 percent of the pig iron production is refined to produce steel. Cast-iron pipe and some fittings and valves are manufactured from pig iron.

The term cast iron may be applied to any iron in which the carbon alloy is more than 1.7 percent. Cast iron has high compressive strength and good wear resistance, but lacks ductility, malleability, and impact strength. Alloying it with nickel, chromium, molybdenum, silicon, or vanadium will improve toughness, tensile strength, and hardness.

Wrought iron is made from pig iron by a process of puddling, squeezing, and rolling. This process removes many of the impurities, and gives the wrought iron a type of fibrous internal structure which promotes workability and resistance to corrosion. It is in the properties induced by the manufacturing process that wrought iron differs from mild steel, since the chemical analysis of the two materials is practically the same.

Wrought iron is used where exceptional ductility is required, or as a structural material where parts are exposed to corrosion or must be welded. It is used in the manufacture of certain piping and rivets.

Ingot iron is a commercially pure iron (99.85 percent Fe), easily formed and possessing good ductility and corrosion resistance. The chemical analysis, structure, and properties of the iron and of the lowest carbon steel are practically the same. The lowest carbon steel, known as dead soft, has about 0.06 percent more carbon content than ingot iron. In iron, the carbon content is considered an impurity; in steel, the carbon is considered an alloying element. The

chief use for ingot iron is for galvanized and enameled sheet.

Steel

Of all the different metals and materials which are used in the construction of ground support equipment, steel is by far the most predominant. Steel is manufactured from pig iron by decreasing the amount of carbon and other impurities present. About 15 pounds of manganese, an indispensible addition in the production of steel, is added to each ton of pig iron.

The steel classification of the Society of Automotive Engineers (SAE) and American Iron and Steel Institute (AISI) is used in specifications for all high-grade steels used in the construction of support equipment. A numerical index system identifies the composition.

The SAE numbers for plain carbon steels and low-alloy steels utilize a four-digit or five-digit number to indicate the composition of the steel. The first digit indicates the type of steel; the second, the percentage of the principal alloying element; and usually the last two or three digits indicate the percentage, in hundreths of 1 percent, of carbon in the steel. For example, the SAE number 4150 indicates molybdenum steel containing 1 percent molybdenum and 50 hundreths of 1 percent carbon. Refer to the SAE numerical index shown in the table 6-2 to see how the various types of steel are classified into four-digit classification numbers.

Table 6-2.—SAE numerical index.

Type of steel	Classification
Carbon	1xxx
Nickel	2xxx
Nickel-chromium	3xxx
Molybdenum	4xxx
Chromium	5xxx
Chromium-vanadium	6xxx
Tungsten	7xxx
Silicon-manganese	9xxx

NOTE: The number system of high-alloy steels differs in some respects. This system is discussed later in this chapter under stainless steels.

While steel of the plain carbon type remains the principal product of the steel mills, so-called alloy or special steels are being turned out in ever increasing tonnage. Let us now consider those alloyed steels and their uses in ground support equipment.

CARBON STEELS.—Steel containing carbon in percentages ranging from 0.10 to 0.30 percent are classed as LOW-CARBON STEEL. The equivalent SAE numbers range from 1010 to 1030. Steels of this grade are used for making such items as safety wire, certain nuts, and threaded rod ends. Low-carbon steel in sheet form is used for some structural members and clamps, and in tubular form for moderately stressed structural parts.

Steels containing carbon in percentages ranging from 0.30 to 0.50 percent are classed as MEDIUM-CARBON STEEL. This steel is especially adaptable for machining or forging and where surface hardness is desirable. It is harder and stronger than low-carbon steel and is used when structural strength is required. It is used in connecting rods, crane hooks, axles, setscrews, etc.

Steels containing carbon in percentages ranging from 0.50 to 1.05 percent are classed as HIGH-CARBON STEEL. The addition of other elements in varying quantities adds to the hardness of the steel. In the fully heat-treated condition it is very hard and will withstand high shear and wear and have little deformation. High-carbon steels are used in the manufacture of drills, taps, dies, and other hand and machine tools which are heat treated after fabrication to develop the hard structure necessary to withstand high shear stress and wear. SAE 1095 in sheet form is used for making flat springs, and in wire form for making coil springs.

NICKEL STEELS.—The various nickel steels are produced by combining nickel with carbon steel. Steels containing from 3 to 3.75 percent nickel are commonly used. Nickel increases the hardness, tensile strength, and elastic limit of steel without appreciably decreasing the ductility. It also intensifies the hardening effect of heat treatment. SAE 2330 steel is used extensively for bolts, terminals, keys, clevises, and pins.

CHROMIUM STEELS.—Chromium steels are high in hardness, strength, and corrosion-resistant properties. SAE 5135 is particularly adaptable for heat-treated forgings which require greater strength and toughness than may be obtained in plain carbon steel. It is used for

such articles as the balls and rollers of antifriction bearings.

NICKEL-CHROMIUM STEELS.—Nickel is the principal alloying element in nickel-chromium steels. In these low-alloy steels the amount of nickel varies from approximately 0.5 percent to 5 percent. The amount of chromium is about one-half that of nickel. For example, SAE 3135 contains 1.10 - 1.40 percent nickel and 0.55 - 0.75 percent chromium. These steels also vary in carbon content. The low-carbon grades are used for gears, pinions, crankshafts, and piston pins. Medium-carbon grades are used for shafts, studs, and bolts. The high-carbon grades, such as SAE 3250, are used for axle shafts, gears, spline shafts, and other parts for heavy-duty work.

CHROME-VANADIUM STEELS.—These are made of approximately 0.18 percent vanadium and about 1 percent chromium. When heat treated, they have strength, toughness, and resistance to wear and fatigue. A special grade of this steel in sheet form can be cold-formed into intricate shapes. It can be folded and flattened without signs of breaking or failure. SAE 6150 is used for making springs; and chrome-vanadium with high-carbon content, SAE 6195, is used for ball and roller bearings.

CHROME-MOLYBDENUM STEELS.—Molybdenum in small percentages is used in combination with chromium to form chrome-molybdenum steel which has various uses in ground support equipment. Molybdenum is a strong alloying element. It raises the ultimate strength of steel without affecting ductility or workability. Molybdenum steels are tough, wear resistant, and hardened throughout from heat treatment. They are especially adaptable for welding, and for this reason are used principally for welded structural parts and assemblies. This type steel has practically replaced carbon steels for the fabrication of most structural parts. For example, a heat-treated SAE 4130 tube is approximately four times as strong as an SAE 1025 tube of the same weight and size.

The most popular series of chrome-molybdenum steel is that series containing 0.25 to 0.55 percent carbon, 0.15 to 0.25 percent molybdenum, and 0.50 to 1.10 percent chromium. These steels, when suitably heat treated, are deep hardening, easily machined, readily welded by either gas or electric methods, and are especially adapted to high-temperature service.

CHROMIUM-NICKEL OR STAINLESS STEELS.—These steels are corrosion-resisting metals. The anticorrosive degree is determined by the surface condition of the metal as well as by the composition, temperature, and concentration of the corrosive agent.

The principal alloying element of stainless steel is chromium, to which nickel may or may not be added. Perhaps the most widely known alloy in this group is the steel that is commonly referred to as 18-8 steel because of its content of 18 percent chromium and 8 percent nickel. One of the distinctive features of 18-8 steel is that its strength can be increased by cold-working.

As stated previously in this chapter, the SAE and AISI number system for high-alloy steels differs from that of plain carbon and low-alloy steels. The AISI number for the high-alloy steels contains three digits. The first digit defines a major series and the second and third digits identify the steel. Occasionally a letter suffix is added to the three digits. This indicates a modification to the basic type steel.

Although some stainless steels are classified in the 200, 400, and 500 series, most are in the 300 series. The most common of these are the 301, 302, 304, 304L, 316, 316L, 321, and 347. Each of these varies slightly as to the amount of carbon, chromium, and/or nickel. In addition, type 321 has titanium added and 347 has columbium added.

Stainless steel may be rolled, drawn, bent, or formed to any shape. Because these steels expand about 50 percent more than mild steel and conduct heat only about 40 percent as rapidly, they are more difficult to weld. Stainless steel, with but a slight variation in its chemical composition, can be used for almost any part of ground support equipment. Some of its more common applications are in the fabrication of structural and machined parts, springs, castings, and tie rods and cables.

NONFERROUS METALS

The term NONFERROUS refers to all metals which have elements other than iron as their principal constituent. Although ferrous metals are used in greater quantities than nonferrous in the construction of support equipment, the nonferrous metals are nevertheless of great importance. This group includes such metals as copper, zinc, lead, aluminum, etc. Some of

the most common nonferrous metals are described in the following paragraphs.

Copper

Copper and copper alloys rank high among commercial metals with respect to desirable properties. Copper is ductile, malleable, hard, tough, strong, wear resistant, machinable, weldable, and corrosion resistant. In addition, it has high tensile strength, fatigue strength, and thermal and electrical conductivity. Copper is easy to work; and although it becomes hard when worked, it can easily be softened by heating it to a cherry red and then letting it cool. Annealing and softening are the only heat-treating procedures that are applied to copper. Seams in copper can be joined by means of riveting, brazing, soft soldering, gas welding, or electric arc welding.

Copper is used in the form of sheets, tubing, and wires, and also in copper alloys such as brass and bronze. It is used to give a protective coating to other metals and to fabricate many special parts.

Zinc

Zinc is used as a protective coating known as galvanizing on steel and iron. Zinc is also used in soldering fluxes and as an alloying element in some brass and bronze. High-purity zinc, in the form of sheets, rods, or special shapes, is sometimes used to protect mechanisms from the effects of galvanic action. Galvanic action, a form of electrolytic corrosion, is discussed in chapter 17.

Lead

Lead is a heavy metal, weighing about 710 pounds per cubic foot. In spite of its weight, however, lead is soft and malleable. It is available in pig and sheet form. In sheet form, it is rolled up on a rod so that the user can unroll and cut off the amount required. The surface of lead is grayish in color, but scratching or scraping the surface will show that the color of the metal is actually white. Because of its softness, lead can be used as backing material when holes are to be punched with a hollow punch, or when shapes are to be hammered from copper sheet. Lead-lined pipe is used for systems that must carry chemicals.

Lead is frequently used in alloyed form. Its low tensile strength can be greatly increased by alloying and by mechanical working. Alloyed with tin, in various proportions, it produces a soft solder. Lead is often added to metal alloys to improve machinability. When working with lead, remember that its dust, fumes, or vapor can be highly poisonous.

Tin

Tin has many important uses as an alloying element. It can be alloyed with copper to produce bronze, and alloyed with lead to produce soft solder. Tin and tin-base alloys have a low fatigue strength and a compressive strength which will accommodate light or medium, but not heavy, loads. Tin, like lead, possesses a good resistance to corrosion; it has the added advantage of being nonpoisonous. When subjected to extremely low temperatures, however, it has a tendency to decompose.

Brass

True brass is an alloy of copper and zinc. Additional elements—aluminum, iron, lead, manganese, magnesium, nickel, phosphorous, and tin—may be added to give the alloy specific properties. Brass with a zinc content of 30 to 35 percent is very ductile, while that containing 45 percent has relatively high strength. MUNTZ METAL is a brass composed of 60 percent copper and 40 percent zinc. It has excellent corrosion-resistant qualities when in contact with salt water. Its strength can be increased by heat treatment. As cast, this metal has an ultimate tensile strength of 50,000 psi and can be elongated 18 percent. It is used in making bolts and nuts, as well as parts that come in contact with salt water. RED BRASS, sometimes termed bronze because of its tin content, is used in fuel and oil line fittings. This metal has good casting and finishing properties and machines freely.

Brass sheets and strips are available in grades known as soft, 1/4 hard, 1/2 hard, full hard, and spring. Hardness is imparted by the process of cold rolling. All grades of brass can be made softer by annealing the metal at a temperature between 500° and 600°F. Overheating can destroy the zinc in the alloy. The brass should be allowed to cool in still air.

Bronze

Bronzes are copper alloys containing tin. The true bronzes have up to 25 percent tin, but those below 11 percent are most common. Most of these alloys contain additional elements such as zinc, lead, iron, aluminum silicon, and phosphorus. Like brass, bronze has excellent corrosion-resistant qualities. It is used in the construction of bushings and tube fittings.

Nickel-Copper Alloys

Monel and K-Monel are alloys in which nickel is the predominating element. Monel contains from 64 to 68 percent nickel, about 30 percent copper, and small amounts of iron, manganese, and cobalt. Monel is harder and stronger than either nickel or copper, and has high ductility. It has many of the qualities of stainless steel, which it resembles in appearance; and its strength and high resistance to corrosion make it an acceptable substitute for steel in a system or service where corrosion resistance is of primary importance. Nuts, bolts, screws, and various fittings are made of Monel. This alloy can be cold-worked, and can be forged and welded.

K-Monel is similar to Monel but has greater tensile strength and greater hardness. Its strength is comparable to that of heat-treated steel, and is often used for instrument parts that must be capable of resisting corrosion.

Inconel

Inconel is a high nickel alloy often used in engine exhaust systems and for other parts where heat resistance is important. This alloy contains 78.5 percent nickel, 14 percent chromium, 6.5 percent iron, and 1 percent of other elements. It offers great resistance to corrosion, and retains its strength at high operating temperatures.

Aluminum and Aluminum Alloys

Commercially pure aluminum is a white lustrous metal and stands second in the scale of malleability, sixth in ductility, and ranks high in resistance to corrosion. Aluminum is combined with various percentages of other metals (generally copper, manganese, magnesium, chromium, or silicon) to form alloys. Aluminum alloys in which the principal alloying ingredients are manganese, magnesium, chromium, or silicon show little attack in corrosion environments. On the other hand, those alloys in which substantial percentages of copper are used are more susceptible to corrosive action. The total percentage of alloying elements is seldom more than 6 or 7 percent in the wrought aluminum alloys.

Aluminum alloys are used in the construction of equipment and structural components requiring high strength/weight ratio and corrosion-resisting qualities. The outstanding characteristic of aluminum is its light weight. In color, aluminum resembles silver, although it possesses a characteristic bluish tinge of its own. Commercially pure aluminum melts at the comparatively low temperature of 1,220°F. It is nonmagnetic and an excellent conductor of electricity.

Commercially pure aluminum has a tensile strength of about 13,000 psi, but by rolling or other cold-working processes its strength may be approximately doubled. By alloying with other metals, together with the use of heat-treating processes, the tensile strength may be raised to as high as 96,000 psi, or to well within the strength range of structural steel.

Aluminum alloy material, although strong, is easily worked, for it is very malleable and ductile. It may be rolled into sheets as thin as 0.0017 inch or drawn into wire 0.004 inch in diameter.

One disadvantage of aluminum alloy is the difficulty of making reliable soldered joints. Oxidation of the surface of the heated metal prevents soft solder from adhering to the material; therefore, to produce good joints of aluminum alloy, a riveting process is used. Some aluminum alloys are also successfully welded.

The various types of aluminum may be divided into two classes—WROUGHT ALLOYS (those which may be shaped by rolling, drawing, or forging), and the CASTING ALLOYS (those suitable for casting in sand, permanent mold, and die castings). Of the two, the wrought alloys are the most widely used in the construction of support equipment, being used in the form of sheets, rivets, tubing, and extruded sections.

WROUGHT ALLOYS.—Wrought alloys are divided into two classes—nonheat treatable and heat treatable. In the nonheat-treatable class, strain hardening (cold-working) is the only means of increasing the tensile strength. Heat treatable alloys may be hardened by heat

treatment, by cold-working, or by the application of both processes.

Aluminum products are identified by a universally used designation system. Under this arrangement, wrought aluminum and wrought aluminum alloys are designated by a four-digit index system.

The first digit of the designation indicates the major alloying element or alloy group, as shown in table 6-3. Thus, 1xxx indicates aluminum of 99.00 percent or greater, 2xxx indicates an aluminum alloy in which copper is the major alloying element, 3xxx indicates an aluminum alloy with manganese as the major alloying element, etc. Although most aluminum alloys contain several alloying elements, only one group (6xxx) designates more than one alloying element

Table 6-3.—Designations for aluminum alloy groups.

Aluminum—99.00 percent minimum and greater	1xxx
Aluminum alloys, grouped by major alloying element	
Copper	2xxx
Manganese	3xxx
Silicon	4xxx
Magnesium	5xxx
Magnesium and silicon	6xxx
Zinc	7xxx
Other element	8xxx

In the 1xxx group, the second digit in the designation indicates modifications in impurity limits. If the second digit is zero, it indicates that there is no special control on the individual impurities. The last two of the four digits indicate the minimum aluminum percentage. Thus, alloy 1030 indicates 99.30 percent aluminum without special control on impurities. Alloys 1130, 1230, 1330, etc., indicate the same aluminum purity with special control on one or more impurities. Likewise, 1075, 1175, 1275, etc., indicate 99.75 percent aluminum.

In the 2xxx through 8xxx groups, the second digit indicates alloy modifications. If the second digit in the designation is zero, it indicates the original alloy, while numbers 1 through 9, assigned consecutively, indicate alloy modification. The last two of the four digits have no special significance. In most cases, these two digits were retained from the previous two-digit numbering system.

The temper designation follows the alloy designation and shows the actual condition of the metal. It is always separated from the alloy designation by a dash.

The letter F following the alloy designation (for example, 3003-F) indicates the "as fabricated" condition, in which no effort has been made to control the mechanical properties of the metal.

The letter O indicates dead soft, or annealed, condition.

The letter W indicates solution heat treated. Solution heat treatment consists of heating the metal to a high temperature followed by a rapid quench in cold water. This is an unstable temper, applicable only to those alloys which spontaneously age at room temperature. Alloy 7075 may be ordered in the W condition.

The letter H indicates strain hardened; that is, cold-worked hand-drawn, or rolled. Additional digits are added to the H to indicate the degree of strain hardening. Alloys in this group cannot be strengthened by heat treatment, hence the term nonheat treatable.

The letter T indicates fully heat treated. Digits are added to the T to indicate certain variations in treatment.

Greater strength is obtainable in the heat-treatable alloys. Therefore, they are used for structural purposes in support equipment in preference to the nonheat-treatable alloys. Some of the most common heat-treatable alloys are 6061, 6062, 6063, 2017, 2024, 2014, 7075, and 7178.

Alloys 6061, 6062, and 6063 are sometimes used for oxygen and hydraulic lines and in some applications as extrusions and sheet metal.

Alloy 2017 is used for rivets, sheet, and some structural members.

Alloy 2024 is used in sheet form and fittings. It may be used whenever 2017 is specified, since it is stronger.

Alloy 2014 is used for extruded shapes and forgings. This alloy is similar to 2017 and 2024 in that it contains a high percentage of copper. It is used where more strength is required than that obtainable from 2017 or 2024.

Alloy 7178 is a relatively new material differing from most other high-strength alloys in that zinc is the main alloying element. Alloy

7178 is used where high strength is necessary. Alloy 7178 contains a small amount of chromium as a stabilizing agent as does alloy 7075.

The most common nonheat-treatable alloys used in the construction of support equipment are 1100, 3003, and 5052. These alloys do not respond to any heat treatment other than a softening, annealing effect. They may be hardened only by cold-working.

Alloy 1100 is used where strength is not an important factor but where weight, economy, and corrosion resistance are desirable.

Alloy 3003 is similar to 1100 and is generally used for the same purposes. It contains a small percentage of manganese and is stronger and harder than 1100, but retains enough workability that it is usually preferred over 1100 in many applications.

Alloy 5052 is used for some hydraulic and fuel lines. Substantially higher strength without too much sacrifice of workability can be obtained in 5052. It is therefore preferred over 1100 and 3003 in many applications.

Alclad is the name given to standard aluminum alloys which have been coated on both sides with a thin layer of pure aluminum. Alclad has very good ocrrosion-resisting qualities. Alclad sheet is available in all tempers of 2014, 2017, 7075, and 7178.

CASTING ALLOYS.—Aluminum casting alloys, like wrought alloys, are divided into two groups. In one, the physical properties of the alloys are determined by the elements added and cannot be changed after the metal is cast. In the other, the elements added make it possible to heat treat the casting to produce desired physical properties.

The casting alloys are identified by a letter preceding the alloy number. This is exactly opposite from the case of wrought alloys in which the letters follow the number. When a letter precedes a number, it indicates a slight variation in the composition of the original alloy. This variation in composition is made simply to impart some desirable quality. In casting alloy 214, for example, the addition of zinc, to increase its pouring qualities, is designated by the letter A in front of the number, thus creating the designation A214.

When castings have been heat treated, the heat treatment and the composition of the casting are indicated by the letter T and an alloying number. An example of this is the sand casting alloy 355 which has several different compositions and tempers and is designated by 355-T6, 355-T51, and A355-T51.

Aluminum alloy castings are produced by one of three basic methods—sand mold, permanent mold, and die cast. In casting aluminum, it must be remembered that in most cases different types of alloys must be used for different types of castings. Sand castings and die castings require different types than those used in permanent molds.

SHOP CHARACTERISTICS OF ALUMINUM ALLOYS.—Aluminum is one of the most readily workable of all the common commercial metals. It can be fabricated readily into a variety of shapes by any conventional method; however, formability varies a great deal with the alloy and temper.

Aluminum is one of the most readily weldable of all metals. The nonheat-treatable alloys can be welded by all methods, and the heat-treatable alloys can be successfully spot welded. The melting point for pure aluminum is 1,220°F, while various aluminum alloys melt at slightly lower temperature. Aluminum products do not show any color changes on being heated, even up to the melting point. Riveting is the most reliable method of joining stress-carrying parts of heat-treated aluminum alloy structures.

IDENTIFYING METALS BY SURFACE APPEARANCE

It is sometimes possible to identify metals by their surface appearance. Table 6-4 indicates the surface colors of some common metals. The outside appearance helps to identify the metal. A newly fractured surface, or a freshly filed surface, offers additional clues.

Examining the outside unfinished surface is not always enough to identify a metal. The color of the metal will put it into a class. This classification is further broken down by examining the surface. An examination often discloses distinctive marks on the surface which were left from the process of manufacture and will aid in determining the proper identity of the metal. Cast iron and malleable iron usually show evidence of the sand mold; low-carbon steel often shows forging marks; and high-carbon steel shows either forging or rolling marks. Feel of the surface may provide another clue. Stainless steel is slightly rough in the unfinished state, but the unfinished surfaces of wrought iron, copper, brass, bronze, nickel,

Table 6-4.—Surface colors of some common metals.

Metals	Color of unfinished, unbroken surface	Color and structure of newly fractured surface	Color of freshly filed surface
White cast iron	Dull gray	Silvery white; crystalline	Silvery white
Gray cast iron	Dull gray	Dark dray; crystalline	Light silvery gray
Malleable iron	Dull gray	Dark gray; finely crystalline	Light silvery gray
Wrought iron	Light gray	Bright gray	Light silvery gray
Low carbon and cast steel	Dark gray	Bright gray	Bright silvery gray
High-carbon steel	Dark gray	Light gray	Bright silvery gray
Stainless steel	Dark gray	Medium gray	Bright silvery gray
Copper	Reddish brown to green	Bright red	Bright copper color
Brass and bronze	Reddish yellow, yellowish green, or brown	Red to yellow	Reddish yellow to yellowish white
Aluminum	Light gray	White; finely crystalline	White
Monel metal	Dark gray	Light gray	Light gray
Nickel	Dark gray	Off-white	Bright silvery white
Lead	White to gray	Light gray; crystalline	White

and monel are smooth. Lead also is smooth, but has a velvety appearance.

METAL IDENTIFICATION TESTS

When the surface appearance of a metal does not give enough information to allow positive identification, metal identification tests may be necessary. A number of such tests are used. Some of these tests are complicated and require special equipment. Others, however, are relatively simple and quite reliable when performed by a skilled person. The spark test and the chip test are discussed in the following paragraphs.

Spark Test

The spark test is made by holding a sample of material against an abrasive wheel. By visually inspecting the spark stream, an experienced metalworker can identify metals with considerable accuracy. The test is fast, economical, convenient, and easily accomplished. No special equipment is required. The test is used for such jobs as identifying a piece of metal selected from scrap. This test will make the salvaging of small pieces of scrap possible where other means of analyzing for identification would be impractical. Identification of scrap is particularly important when selecting material for cast iron or cast steel heat treatment.

When a piece of iron or steel is held in contact with a high-speed abrasive wheel, small particles of the metal are torn loose so rapidly that they become red hot. As these glowing bits of metal leave the wheel they follow a path

(trajectory) called the carrier line. This carrier line is easily followed with the eye, especially if observed against a dark background.

The sparks given off, or the lack of sparks, assist in identifying the metal. The length of the spark stream, its color, and the form of sparks are features used in the identification process. Figure 6-1 illustrates the terms used in referring to various fundamental spark forms produced in spark testing.

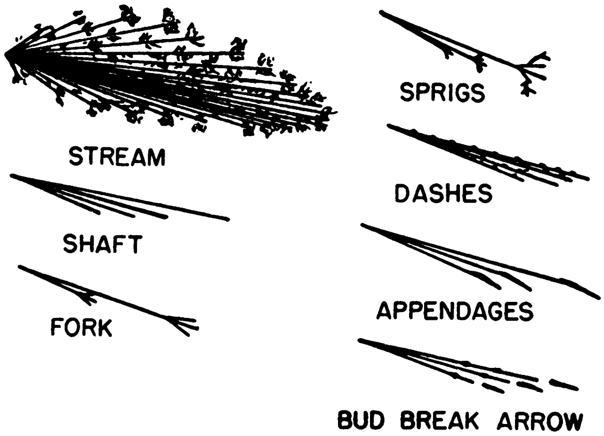

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Figure 6-1.—Meaning of the terms used in spark testing.

Steels having the same carbon content but differing alloying elements are not always easily identified because alloying elements affect the carrier lines, the bursts, or the forms of characteristic bursts in the spark picture. The effect of the alloying element may retard or accelerate the carbon spark, or make the carrier line lighter or darker in color. Molybdenum, for example, appears as a detached, orange-colored, spearhead on the end of the carrier line. Nickel seems to suppress the effect of the carbon burst. However, the nickel spark can be identified by tiny blocks of brilliant white light. Silicon suppresses the carbon burst even more than nickel. When silicon is present, the carrier line usually ends abruptly in a white flash of light.

Spark testing may be accomplished with either a portable or a stationary grinder. In either case, the speed on the outer rim of the wheel should be not less than 4,500 feet per minute, and the abrasive wheel should be rather coarse, very hard, and kept clean to produce a true spark.

To make a spark test, the piece of metal is held on the wheel in such a manner that the spark stream crosses the operator's line of vision. The sample must be held against the wheel at a pressure to produce the proper length stream without reducing the speed of the grinder. Excessive pressure increases the temperature of the spark stream, which in turn increases the temperature of the burst, thereby giving the appearance of higher carbon content than that of the metal being tested.

When making the test, keep the eyes focused at a point about one-third the distance from the tail end of the spark stream. Watch only those sparks that cross the line of vision and try to form a mental image of the individual spark.

Referring now to figure 6-2, notice that in low-carbon steel (A) the spark stream is long (about 70 inches normally) and the volume is moderately large. In high-carbon steel (B), the stream is shorter (about 55 inches) and the volume larger. The few sparklers which may occur at any place in low-carbon steel are forked, while in high-carbon steel they are small and repeating. Both metals produce a spark stream white in color.

Gray cast iron (C) produces a stream of sparks about 25 inches in length. The sparklers are small and repeating, and their volume is rather small. Part of the stream near the grinding wheel is red, while the outer portion is straw colored.

Monel metal and nickel (D) form almost identical spark streams. The sparks are small in volume and orange in color. The sparks form wavy streaks with no sparklers. Because of the similarity of the spark picture, these metals must be distinguished from each other by some other method.

Stainless steel (E) produces a spark stream approximately 50 inches in length of moderate volume with few sparklers. The sparklers are forked. The stream next to the wheel is straw colored, while at the end it is white.

The wrought iron spark test (F) produces a spark stream about 65 inches in length. The stream is of large volume with few sparklers.

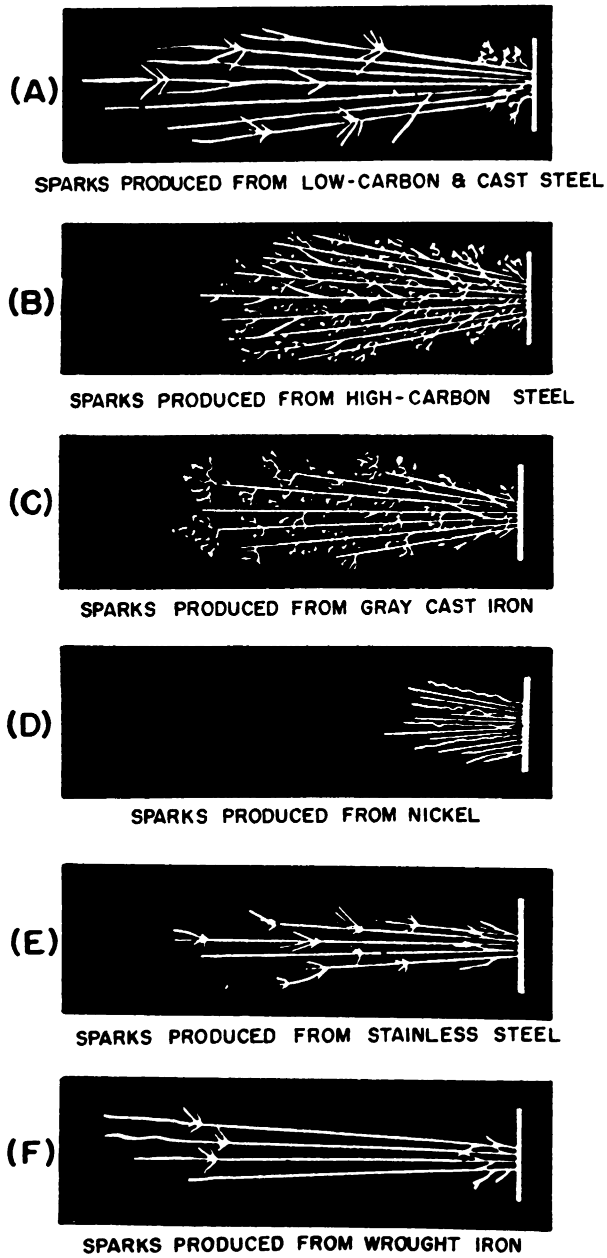

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Figure 6-2.—Sparks formed by common metals.

The sparklers show up toward the end of the stream and are forked. The stream next to the grinding wheel is straw colored, while the outer end of the stream is a bright red.

Chip Test

The chip test is made by removing a small amount of material from the metal specimen with a sharp cold chisel. The material removed will vary from small broken fragments to a continuous strip. The chip may have smooth sharp edges. It may be coarse grained or fine grained. It may have sawlike edges where it has been cut. The size of the chip is important in identifying the metal. The ease with which the chipping can be done should also be taken into consideration. Information concerning the identification of metals by chip test is contained in table 6-5.

METAL-WORKING MACHINES AND PROCEDURES

The ASH spends a large portion of his time working with metal. Therefore, he must be familiar with such metal-working processes as cutting, bending, drilling, tapping, forming, riveting, etc., and also with the machines which make this work faster and easier.

The ASH striker should already be familiar with the more commonly used handtools and how to use them properly; for example, how to measure, drill, use a file or hacksaw, and lay out a piece of metal. Proper usage of the common handtools basic to many ratings is discussed in detail in Tools and Their Uses, NavPers 10085-B. Additional information concerning the types and usage of tools peculiar to the ASH rating is contained in chapter 5 of this manual.

CUTTING SHEET METAL

Cutting of sheet metal is a common occurrence for the ASH. Once a project has been laid out on the metal, the next step is to cut it out. The type of cutting equipment to be used depends primarily upon the type and thickness of the material. Another consideration is the size and number of pieces to be cut. A few fairly thin pieces of comparatively soft metal may be more readily turned out by hand-trimming methods; but for harder metals, faster output, and generally better workmanship results, machines designed for metal cutting purposes are used.

Table 6-5.—Identification of metals by chip test.

Metals	Chip characteristics	Metals	Chip characteristics
White cast iron	Chips are small, brittle fragments. Chipped surfaces not smooth.	Copper	Chips are smooth, with saw-tooth edges where cut. Metal is easily cut. A chip can be cut as a continuous strip.
Gray cast iron	Chips are about 1/8 inch in length. Metal not easily chipped; therefore, chips break off and prevent smooth cut.	Brass and bronze	Chips are smooth, with saw-tooth edges. These metals are easily cut, but chips are more brittle than chips of copper. Continuous strip is not easily cut.
Malleable iron	Chips are from 1/4 to 3/8 inch in length (larger than chips from cast iron). Metal is tough and hard to chip.		
Wrought iron	Chips have smooth edges. Metal is easily cut or chipped, and a chip can be made as a continuous strip.	Aluminum and aluminum alloys	Chips are smooth, with saw-tooth edges. A chip can be cut as a continuous strip.
Low-carbon and cast steel	Chips have smooth edges. Metal is easily cut or chipped, and a chip can be taken off as a continuous strip.	Monel	Chips have smooth edges. Continuous strip can be cut. Metal chips easily.
		Nickel	Chips have smooth edges. Continuous strip can be cut. Metal chips easily.
High-carbon steel	Chips show a fine grain structure. Edges of chips are lighter in color than chips of low carbon steel. Metal is hard, but can be chipped in a continuous strip.	Lead	Chips of any shape may be obtained because the metal is so soft that it can be cut with a knife.

CUTTING EQUIPMENT

Machines used in cutting sheet metal may be divided into two groups—manually operated and power operated. Each type of cutting machine has a definite cutting capacity which should never be exceeded. A few of the more common types that are available to the ASH are described in this section.

Squaring Shears

Squaring shears (fig. 6-3) are used for cutting and squaring sheet metal. They may be foot operated or power operated. Squaring shears consist of a stationary blade attached to a bed, and a movable blade attached to a crosshead. To make a cut, the work is placed in the desired position on the bed of the machine and the blade

is moved through its downward stroke. The stroke of the cutter blade is always identical in its relation to the bed. Foot-powered squaring shears are equipped with a spring which raises the blade when foot pressure is taken off the treadle. A scale graduated in fractions of an inch is scribed on the bed. Two side guides, consisting of thick steel bars, are fixed to the bed, one on the left and one on the right. Each is placed so that its inboard edge creates a right angle with the cutting edge of the bed. These bars are used to align the metal when absolutely square corners are desired. When cuts other than right angles are to be made across the width of a piece of metal, the beginning and ending points of the cut must be determined and marked in advance. The work is then placed into position on the bed, and the beginning and ending marks carefully aligned with the cutting edge of the bed, prior to making the cut.

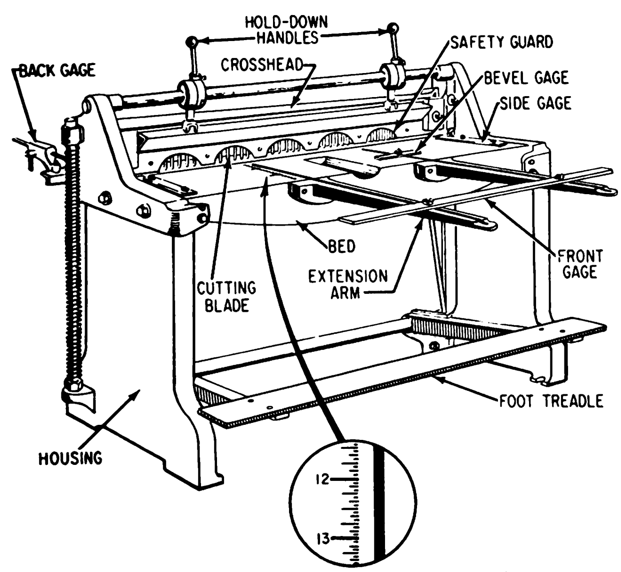

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Figure 6-3.—Squaring shears.

A holddown mechanism operated by holddown levers (fig. 6-3) is incorporated in front of the movable cutting edge in the crosshead. Its purpose is to clamp the work firmly in place while the cut is being made. The clamp is quickly and easily made—the operator merely rotates the lever toward himself and the holddown lowers into place. A firm downward pressure on the lever at this time should rotate the mechanism over center on its eccentric cam and lock the holddown in place. Reverse the action to release the work.

Three distinctly different operations—cutting to a line, squaring, and multiple cutting to a specific size—may be accomplished on the squaring shears. When cutting to a line, proceed as above, place the beginning and ending marks on the cutting edge and make the cut. Squaring requires a sequence of several steps. First, square one end of the sheet with one side. Then square the remaining edges, holding one squared end of the sheet against the side guide and making the cut, one edge at a time, until all edges have been squared.

When several pieces are to be cut to the same dimensions, make use of the adjustable gage stop with which most squaring shears are equipped. This stop is located behind the bed cutting edge, and its purpose is to limit the amount of metal that can be slipped between the cutting edges of the blade and bed. The supporting rods for the stop gage are graduated in inches and fractions of an inch, and the gage bar is rigged so that it may be set and fixed at any point on the rods. With the gage set at the desired distance from the cutting blade, push each piece to be cut against the stop. It is then possible to cut all pieces to the same dimensions without measuring and marking each one separately. (NOTE: Physically measure the first piece in such a series to make sure that the stop is accurately set.)

Throatless Shears

Throatless shears (fig. 6-4) are constructed so that sheets of any length may be cut and the metal turned in any direction during the cutting operation. Thus, irregular lines can be followed, or notches made without distorting the metal. This type of throatless shears is essentially an adaptation of heavy hand shears or snips in which the handles are removed, one blade secured to a base, and a long lever attached to the tip of the movable blade. The heavy duty throatless shears are capable of cutting stainless steel up to 0.083 inch in thickness.

Hand Bench Shears

The hand bench shears are similar in operation to a paper cutter. They have one fixed

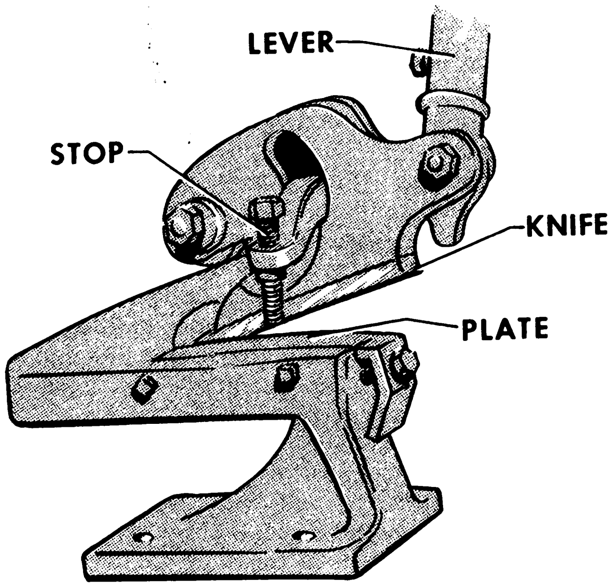

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Figure 6-4.—Throatless shears.

blade and a movable blade, hinged at the back, similar to the throatless shears except that the blades are straight and, therefore, used only for straight cutting. Some bench shears have a punching attachment on the end of the frame opposite the shearing blades. This attachment is for punching holes in metal sheets.

For cutting stock that is narrower in width than the length of the blades, the lever of the shears can be pulled all the way down. When cutting larger pieces, a continuous series of short bites should be made, since complete closing of the blade tends to tear the sheet at the end of each cut.

Unishear

Unishear is a trade name for a type of portable power shears, used for cutting curves and notches as well as straight-line cutting.

This tool might be called a power-operated, combination snips. It has two short blades. The lower blade is held in a fixed position. The upper blade moves up and down in short strokes at a high rate of speed. Its chewing motion, not unlike a feeding rabbit, is the basis for the widely used nickname of this power tool—"nibblers." The tool will cut metal up to its rated capacity which should never be exceeded. Figure 6-5 illustrates an 18-gage Unishear.

The cutting blades are easily removed for sharpening and replacement. The machine will cut as fast as it can be fed up to 15 feet per minute. This is a ruggedly constructed machine; and for satisfactory performance, the best of care is necessary. It should be kept cleaned and oiled at all times.

Hand-Operated Turret Punch

A hand-operated turret punch is shown in figure 6-6. Twelve mated punches and dies are mounted in a rotating turret. Each die block has the size of hold it will punch, as well as the thickness of the material it will accommodate, stamped on the front. These capacities are for mild steel, and this must be kept in mind when punching stainless steel or other alloys.

The operation of the turret punch is simple: Release the locking handle on the side of the punch frame, rotate the turret until the desired punch set is lined up with the actuating mechanism (ram), then lock the turret into position. Punch the hole by pulling the operating lever toward the operator, which actuates the ram and punch.

CUTTING PLATE AND BAR STOCK

The most common method of cutting plate is to use the oxyacetylene cutting torch, as described in chapter 7 of this training manual. However, plate and bar stock may also be cut with various tools and machines. The power hacksaw is often used for this purpose and therefore is discussed in the following paragraphs.

Power Hacksaw

Power hacksaws (fig. 6-7) are used to cut iron or steel shafts, plates, or straps required in repairing equipment. A power saw can do these jobs much faster than a handsaw, and the finished cut will have a straight edge. A straight edge is assured if the metal to be cut is clamped securely in the vise provided on the power saw table. Be sure the saw blade is securely fastened in the blade holder.

In some shops where the power saw is used extensively, a small water container with an adjustable pipe is suspended over the saw blade. When the saw is in operation, water drips on

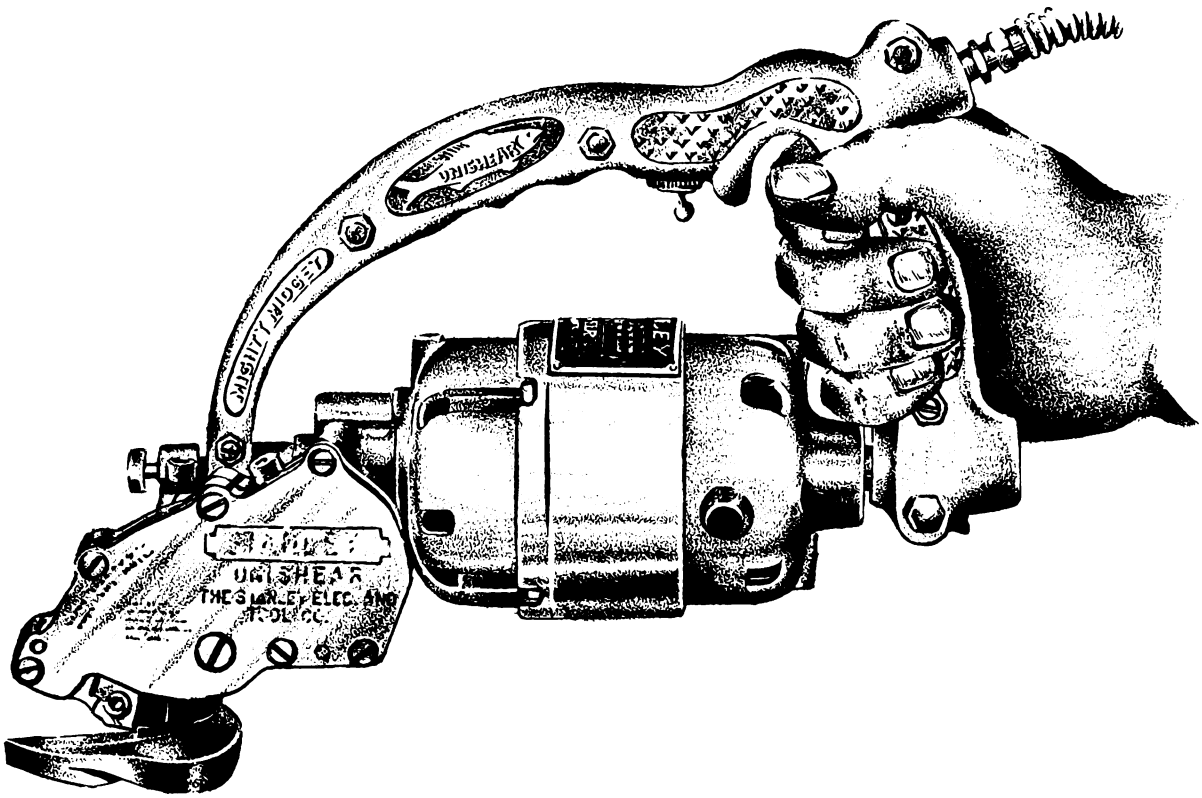

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Figure 6-5.—18-gage Unishear.

the saw blade to prevent overheating. When using the power saw, see that the container has sufficient water, and that the water is directed on the saw blade.

Saw blades are made of special tool steel and will cut well for a long time if used properly. However, a saw blade which is loose in its holder and one which binds during the sawing stroke will break easily. To keep the blade from breaking, the material being cut must be tight in the vise which holds it, and the saw blade and holder must be kept from dropping when the cut is completed. Many power saws have an automatic tripping device which shuts the power off when the cut is completed.

MACHINE FORMING OF SHEET METAL

There are two types of sheet metal forming machines. One type, the slip-roll forming machine, is used to form the complete sheet of metal. The other type is the rotary machine, which is used to shape or form the edge of the metal. These machines are described in the following paragraphs.

Slip-Roll Forming Machine

Sheet metal can be formed into curved shapes over a pipe or a mandrel, but the slip-roll forming machine (fig. 6-8) is much easier to use and produces more accurate bends. Rolling machines are available in various sizes and capacities; some are hand operated, like the one shown in figure 6-8, and others are power operated.

The machine shown in the illustration has two rollers in the front and one roller at the rear. Adjusting screws on each end of the machine control the height and angle of the rear roll and control the distance between the front rolls. By varying the adjustments, the machine

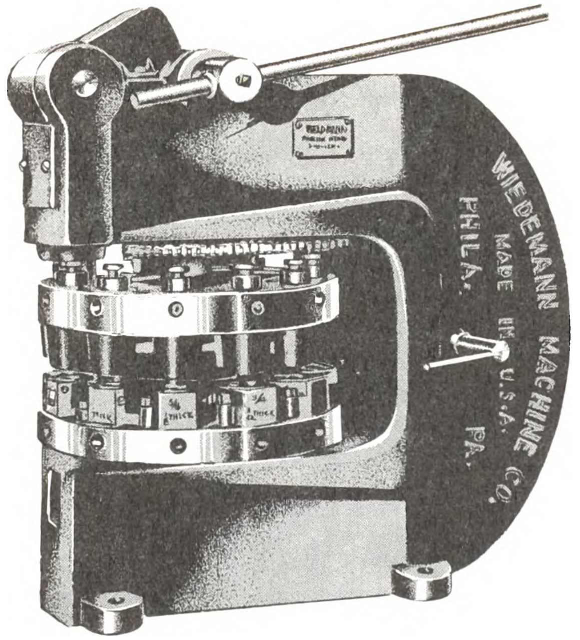

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Figure 6-6.—Hand-operated turret punch.

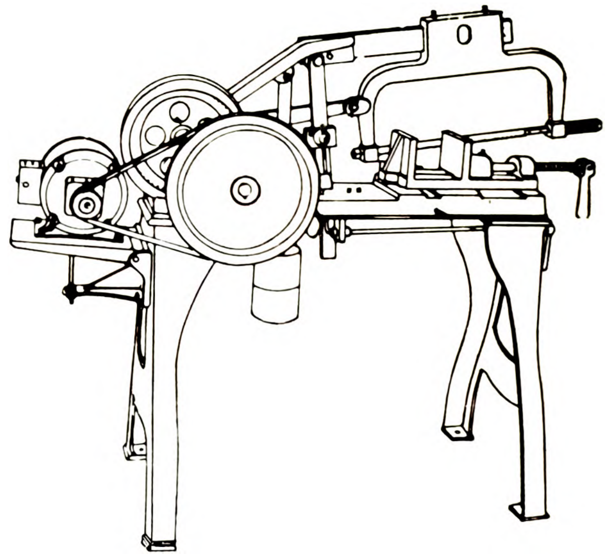

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Figure 6-7.—Power hacksaw.

can be used to form cylinders, cones, and other curved shapes. The front rolls grip the metal and pull it into the machine; therefore, the adjustment of distance between the two front rolls is made on the basis of the thickness of the sheet being worked.

To form a cylinder in the machine (fig. 6-9), follow this procedure.

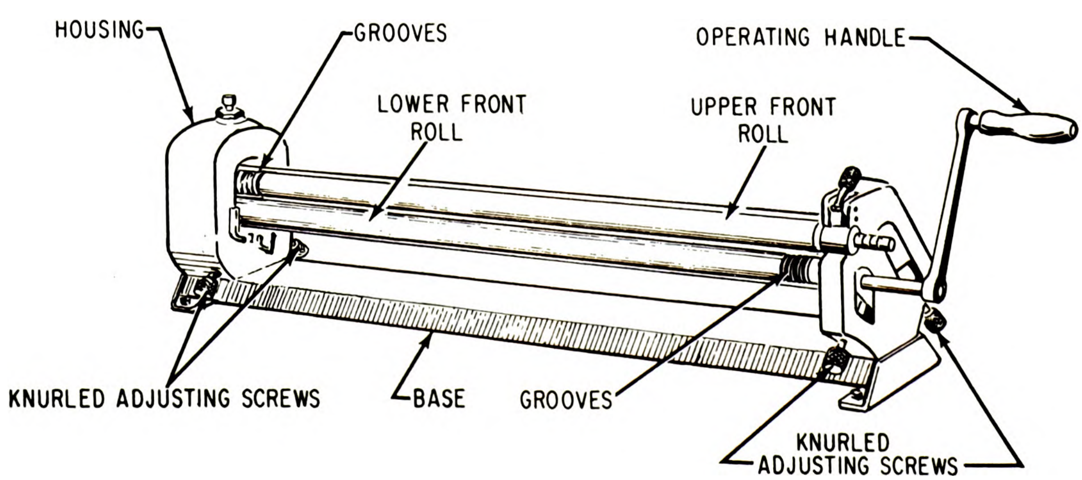

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Figure 6-8.—Slip-roll forming machine.

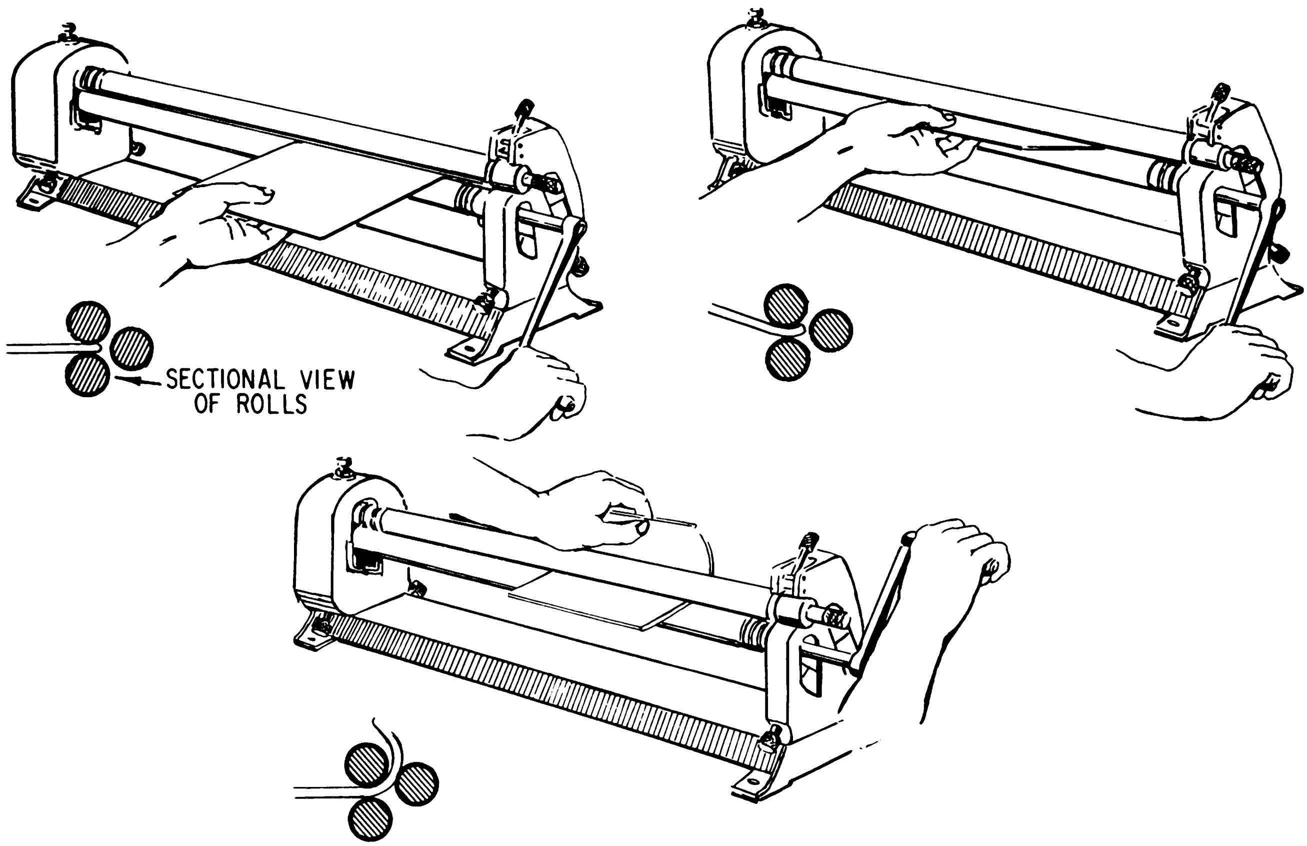

Figure 6-9.—Forming a cylinder.

1. Adjust the front rolls so that they will grip the sheet properly.
2. Adjust the rear roll to a height that is less than enough to form the desired radius of the cylinder.
3. Check to be sure that all three rolls are parallel. (Same space exists between any two rollers at each end of the rollers.)
4. Start the sheet into the space between the two front rolls. As soon as the front rolls have gripped the sheet, raise the free end of the sheet slightly.
5. Pass the entire sheet through the rolls. This forms part of the curve required for the cylinder.
6. Set the rear roll higher to form a shorter radius.
7. Turn the partially formed sheet end over end and again pass it through the rolls.
8. Continue turning the sheet end over end and passing it through the rolls, each time adjusting the rear roll for a new radius, until a truly cylindrical shape has been formed.
9. Remove the cylinder from the machine. The top front roll has a quick-releasing device by which one can release one end of the roll. This allows the released end of the roll to be raised and the newly formed cylinder slipped off just as one would slip a ring from his finger.

Conical shapes can be formed by setting the back roll at an angle before running the sheet through it, or they can be made with the rolls parallel. (See fig. 6-10.) To make a cone with the rolls parallel, the sheet must be fed through the rolls in such a manner that the element lines (A-A', B-B', etc., in the illustration) pass over the rear roll in a line parallel to the roll. This involves slipping the large end of the cone

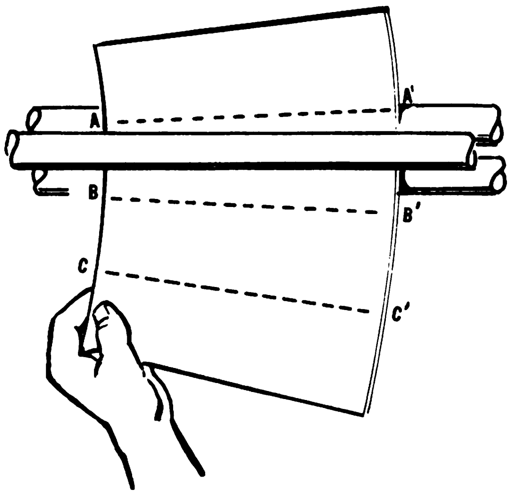

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Figure 6-10.—Rolling a conical shape.

through the rolls at a slightly faster rate than the small end is being rolled through.

The grooves at the end of the rolls can be used to form circles of wire or rod; they can also be used to roll wired edges, as shown in figure 6-11.

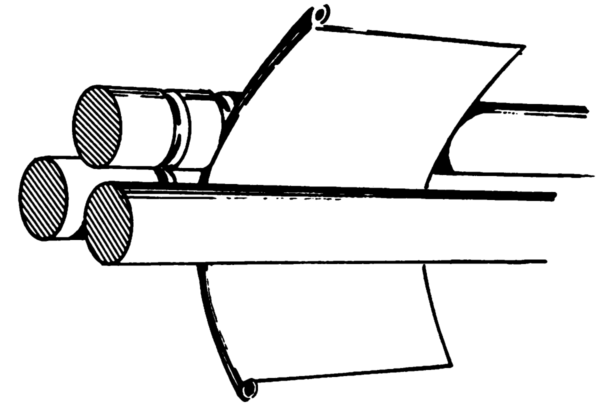

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Figure 6-11.—Rolling a wired edge.

Rotary Machine

The rotary machine (fig. 6-12) is used on cylindrical and flat sheet metal to shape the edge or to form a bead along the edge. Various shaped rolls (some illustrated in fig. 6-13) can be installed on the rotary machine to perform the following operations—beading, turning, wiring, crimping, and burring. These operations are described in the following paragraphs.

BEADING ROLLS.—Beading rolls are used for turning beads (grooves) on such items as tubing, cans, and buckets; and for stiffening and gripping. Beads may also be placed on sheet stock that is to be welded. There are several different types of beading rolls. Those shown in figure 6-14 are the single bead rolls. Whenever beading, the groove should not be made too deeply in a single rotation as this tends to weaken the metal.

TURNING ROLLS.—Turning rolls are used for turning an edge to receive a stiffening wire. When turning an edge, rest the cylinder to be

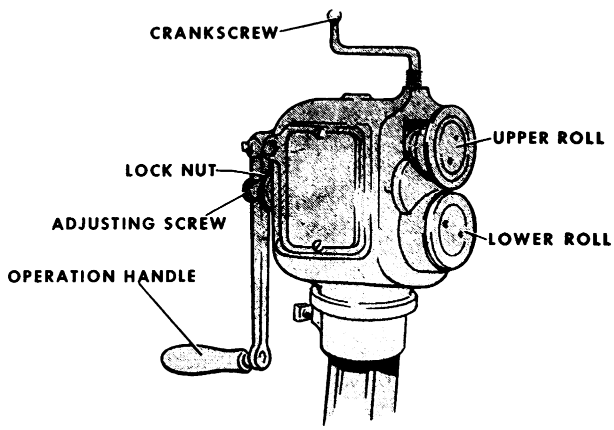

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Figure 6-12.—Rotary machine.

wired on the lower wheel and press against the gage. The gage is adjusted according to the size of wire to be used. With the work set in place, bring down the upper roll until it grips the metal. Turn the crank slowly, holding the metal so that it will feed into the rolls while continuing to press against the guide. After the first revolution, gradually raise the metal until it touches the outer face of the top roll. Remove the stock by raising the top roll.

WIRING ROLLS.—Wiring rolls are used to finish the wired edges prepared in the turning rolls. To use the wiring rolls, adjust the top

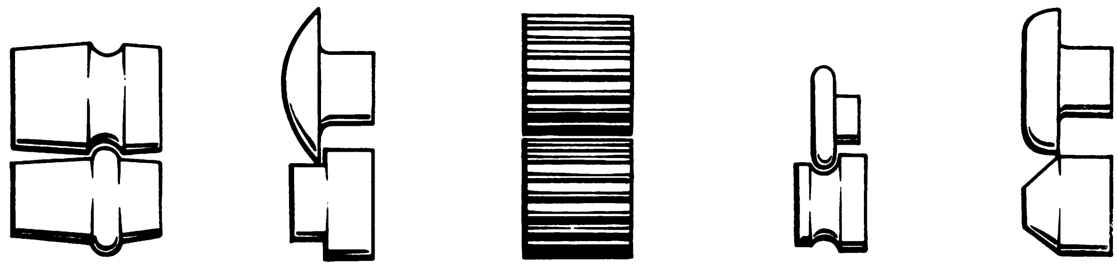

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Figure 6-13.—Roll dies used on rotary machine.

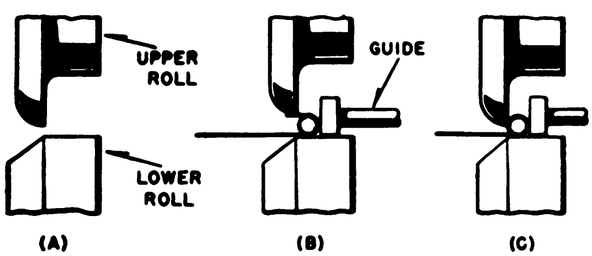

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Figure 6-14.—Wiring operation.

roll so that it is directly above the point on the lower roll where the beveled and flat surfaces meet, as shown in (A) of figure 6-14. Adjust the guide to the position shown in (B), then bring the top roll down so that it will turn the edge of the metal as shown in (C). Remove the stock from the machine by raising the top roll.

CRIMPING ROLLS.—Crimping rolls are used to make one end of a pipe smaller than the other so that two sections may be slipped together, one end into the other. A bead is placed on a pipe first, then it is crimped. The bead forms a shoulder to keep the pipe from slipping too far into the adjoining section.

BURRING ROLLS.—Burring is perhaps the most difficult operation performed on a rotary machine. Before placing the work in the machine, make sure that the cylinder or circular disc to be burred is cut or formed as perfectly round as possible. Then adjust the gage on the machine so that the space between the inside of the upper roll and the gage is set to the width of the burr. Next, place the object between the rolls and against the gage, and lower the upper roll until it scores the material slightly. Now turn the crank slowly, allowing the metal to slide between the thumb and fingers. Apply a slight upward pressure as the metal passes between the rolls. After the first revolution, lower the top roll and again pass the metal between the rolls. Repeat this process, raising the edge slightly with each complete revolution of the material until the edge has been burred to the proper angle.

BENDING SHEET METAL

Straight-line bends and folds in sheet metal are ordinarily made on the cornice brake and bar folder; however, a considerable amount of bending is also carried out by hand-forming methods. Hand forming may be accomplished by using stakes, blocks of wood, angle iron, a vise, or the edge of a bench.

Bending Over Stakes

Stakes are used to back up sheet metal for the forming of many different curves, angles, and seams in sheet metal. Stakes are available in a wide variety of shapes, some of which are shown in figure 6-15. The stakes are held securely in a stake holder or stake plate (also illustrated) which is anchored in a workbench. The stake holder contains a variety of holes to fit a number of different types of shanks.

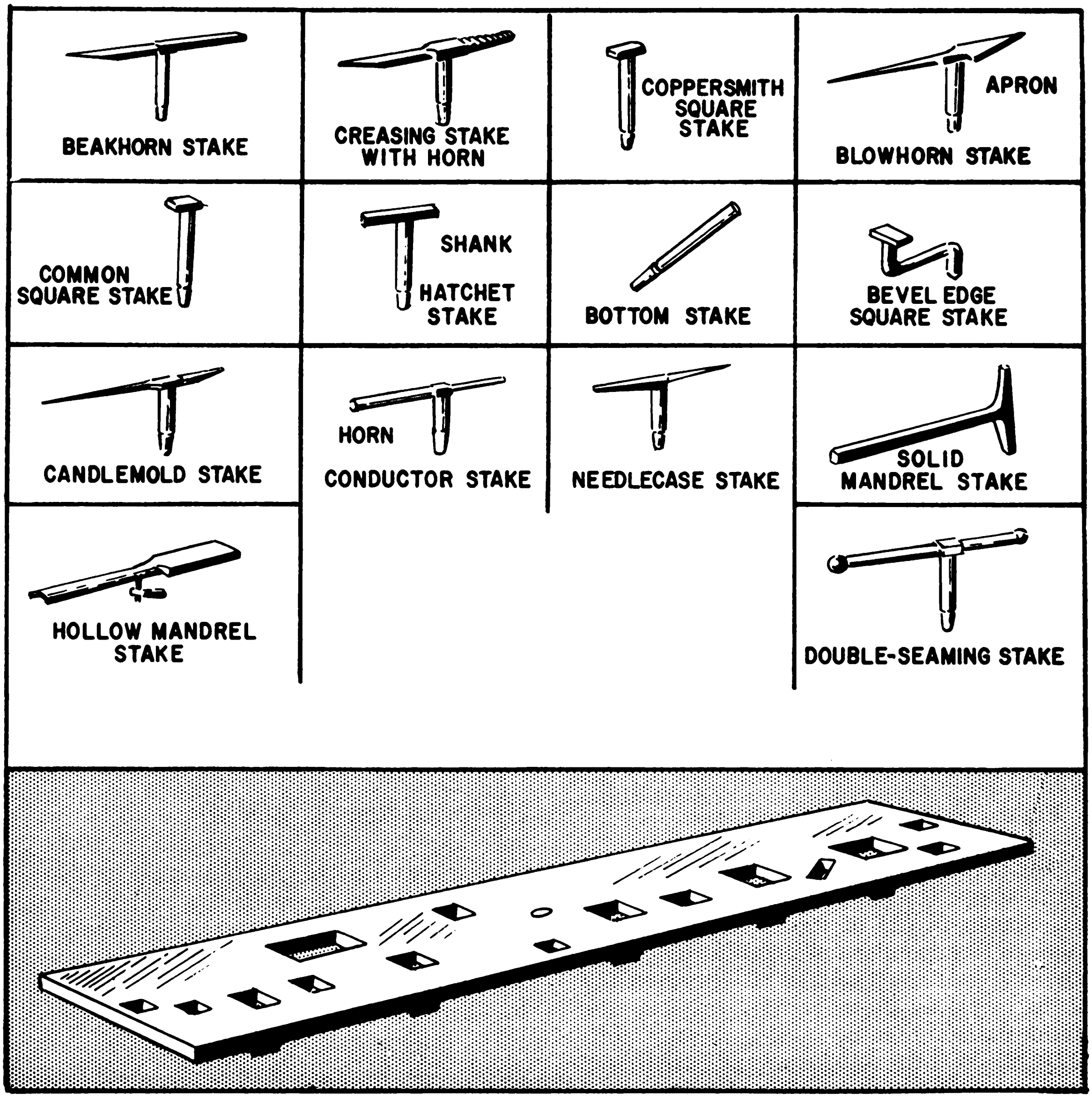

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Figure 6-15.—Stakes and stake plate.

Although stakes are by no means delicate, they must be handled with reasonable care. They must not be used as backing when chiseling holes or notches in sheet metal, or when performing any other job which might damage the faces of the stakes.

Bending in a Vise

Straight-line bends of comparatively short sections can be made by hand with the aid of wooden or metal bending blocks. After the part has been laid out and cut to size, clamp it

rigidly along the bend line between two forming blocks held in a vise. The forming blocks usually have one edge rounded to give the desired bend radius. (See fig. 6-16). By tapping lightly with a rubber, plastic, or rawhide mallet, bend the metal protruding beyond the bending block to the desired angle.

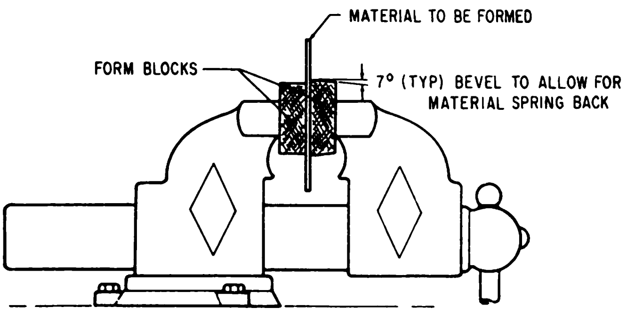

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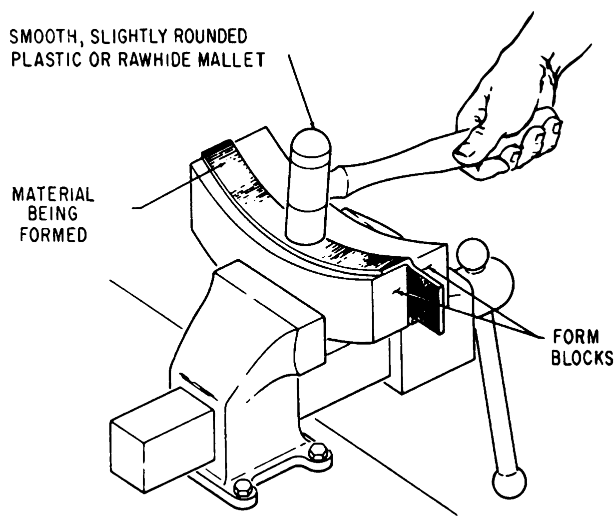
Figure 6-16.—Preparation for straight bend by hand.

Start tapping at one end, and work back and forth along the edge, making the bend gradually and evenly. Continue this process until the protruding metal is bent to the desired angle. If a large amount of metal extends beyond the bending blocks, maintain enough hand pressure against the protruding sheet to prevent the metal from bouncing. Remove any irregularity in the flange by holding a straight block of hardwood edgewise against the bend and striking it with heavy blows of a hammer or mallet. If the amount of metal protruding beyond the bending blocks is small, make the entire bend by using the hardwood block and hammer.

Curved flanged parts have mold lines that are either concave or convex. The concave flange is formed by stretching, while the convex flange is formed by shrinking. Such parts are shaped with the aid of hardwood or metal form blocks. These blocks are made in pairs and specifically for the shape of the part being formed. Each pair fits exactly and conforms to the actual dimension and contour of the finished article.

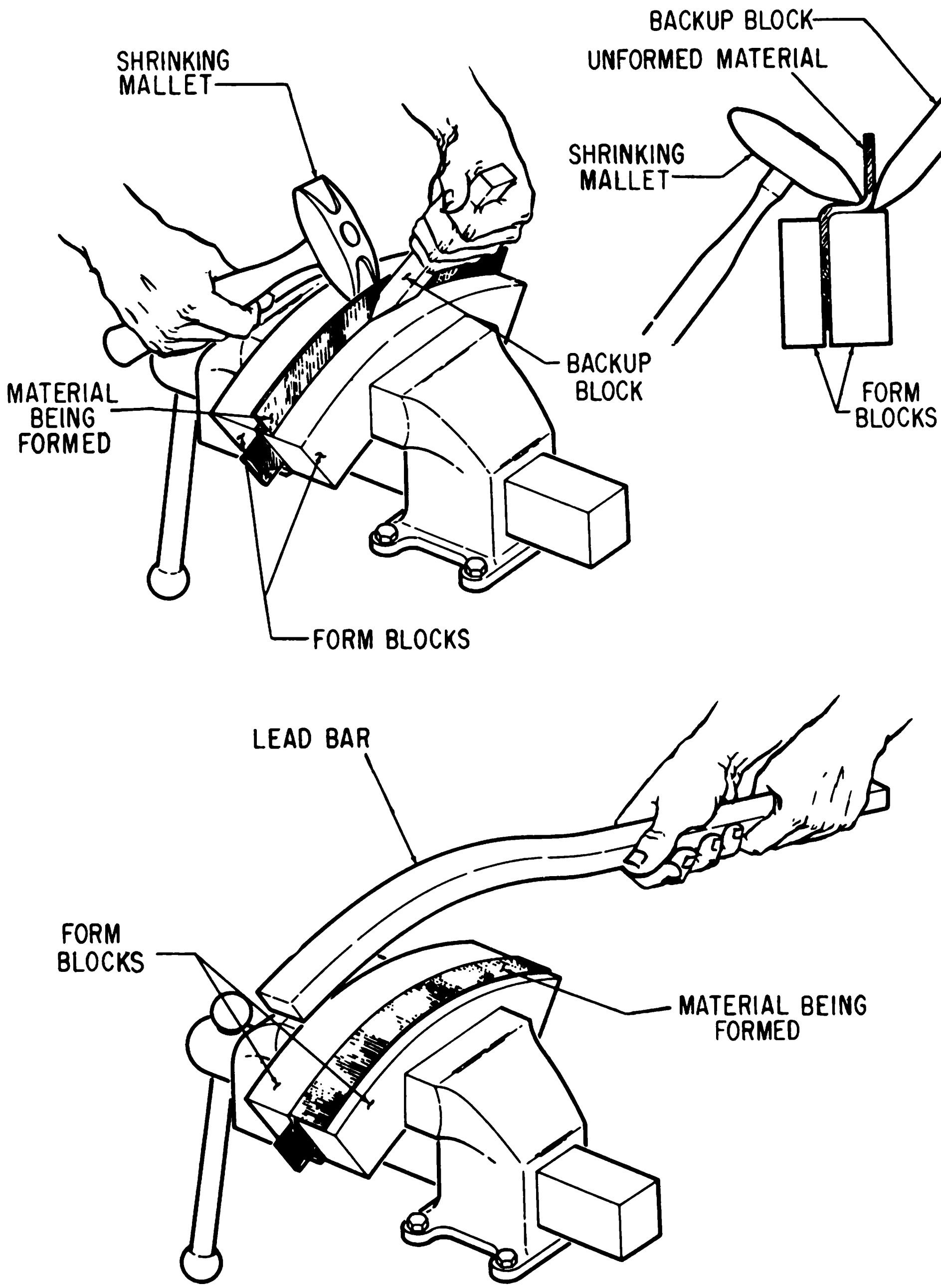
Cut the material to be formed to size, allowing about one-quarter inch of excess material for trim. File and smooth the edges of the material to remove all nicks caused by the cutting tools. This reduces the possibility of the material cracking at the edges during the forming operation. Place the material between the form blocks and clamp tightly in a vise so that the material will not move or shift. Clamp the work as closely as possible to the particular area being formed to prevent strain on the form block and to keep the material from slipping.

Concave surfaces are formed by stretching the material over a form block.(See fig. 6-17.) Using a plastic or rawhide mallet with a smooth, slightly rounded face, start hammering at the extreme ends of the part, and continue toward the center of the bend. This procedure permits some of the material at the ends of the part to be worked into the center of the curve where it will be needed. Continue hammering until the metal is gradually worked down over the entire flange and flush with the form block. After the flange is formed, trim off the excess material and check the part for accuracy.



AM.274
Figure 6-17.—Forming concave hand bend.

Convex surfaces are formed by shrinking the material over a form block. (See fig. 6-18.) Using a wooden or plastic shrinking mallet and a backup or wedge block, start at the center of the curve and work toward both ends. Hammer the flange down over the form, striking the metal with glancing blows at an angle of approximately 45 degrees, and with a motion that will tend to pull the part away from the radius



AM.275

Figure 6-18.—Forming convex hand bends.

of the form block. While working the metal down over the form block, the wedge block is used to keep the edge of the flange as nearly perpendicular to the form block as possible. The wedge block also lessens the possibility of buckles and of splitting or cracking the metal.

Another method of hand forming convex flanges is by using a lead bar or strap. The

material, while secured in the form block, is struck by the lead strap which takes the shapes of the part being formed and forces it down against the form block. One advantage in using this method is that the metal is formed without marring or wrinkling and is not thinned out as much as it would be by other methods of hand forming. This method is also illustrated in figure 6-18. After the flange is formed by either method, trim off the excess material and check the part for accuracy.

Bending on a Brake

The easier and most accurate method of making straight-line bends on a piece of sheet metal is by the use of a box and pan brake or a cornice brake. The use of these brakes is relatively simple; however, if they are not used correctly, the time and the work involved in computing and laying out of bend allowance, as well as the metal, are wasted. Before bending any work demanding an accurate bend radius and definite leg length, the settings of the brake should be checked with a piece of scrap metal. When making an ordinary bend on a brake, place the sheet to be bent on the bed so that the bend line is directly under the upper jaw or clamping bar, then pull down the clamping bar handle. This brings the clamping bar down to hold the sheet firmly in place. Set the stop for the proper angle or amount of bend, and make the bend by raising the bending leaf until it strikes the stop. If more than one bend is to be made, bring the next bend line under the clamping bar and repeat the bending procedure.

CORNICE BRAKE.—The cornice brake (fig. 6-19) is designed for bending large sheets of metal. It is adjustable for clamping a wide variety of metal thicknesses and for bending this metal to a variety of radii.

The brake is equipped with a stop gage, consisting of a rod, a yoke, and a setscrew, by means of which the travel of the bending leaf is limited. This is a useful feature when it is desired to make a number of pieces with the same angle of bend.

The standard cornice brake is extremely useful for making single hems, double hems, lock seams, and various other shapes, some of which require the use of molds. The molds are fastened to the bending leaf of the brake by means of friction clamps, in such a position that the work can be formed over them. Figure 6-20 shows sheet that is ready to be formed over a mold attached to a cornice brake.

BOX AND PAN BRAKE.—The box and pan brake (fig. 6-21) is often called the finger brake since it does not have one solid upper jaw as does the cornice brake, but instead is equipped with a series of steel fingers of varying widths. The finger brake can be used to do everything that the cornice brake can do and several things that the cornice brake cannot do.

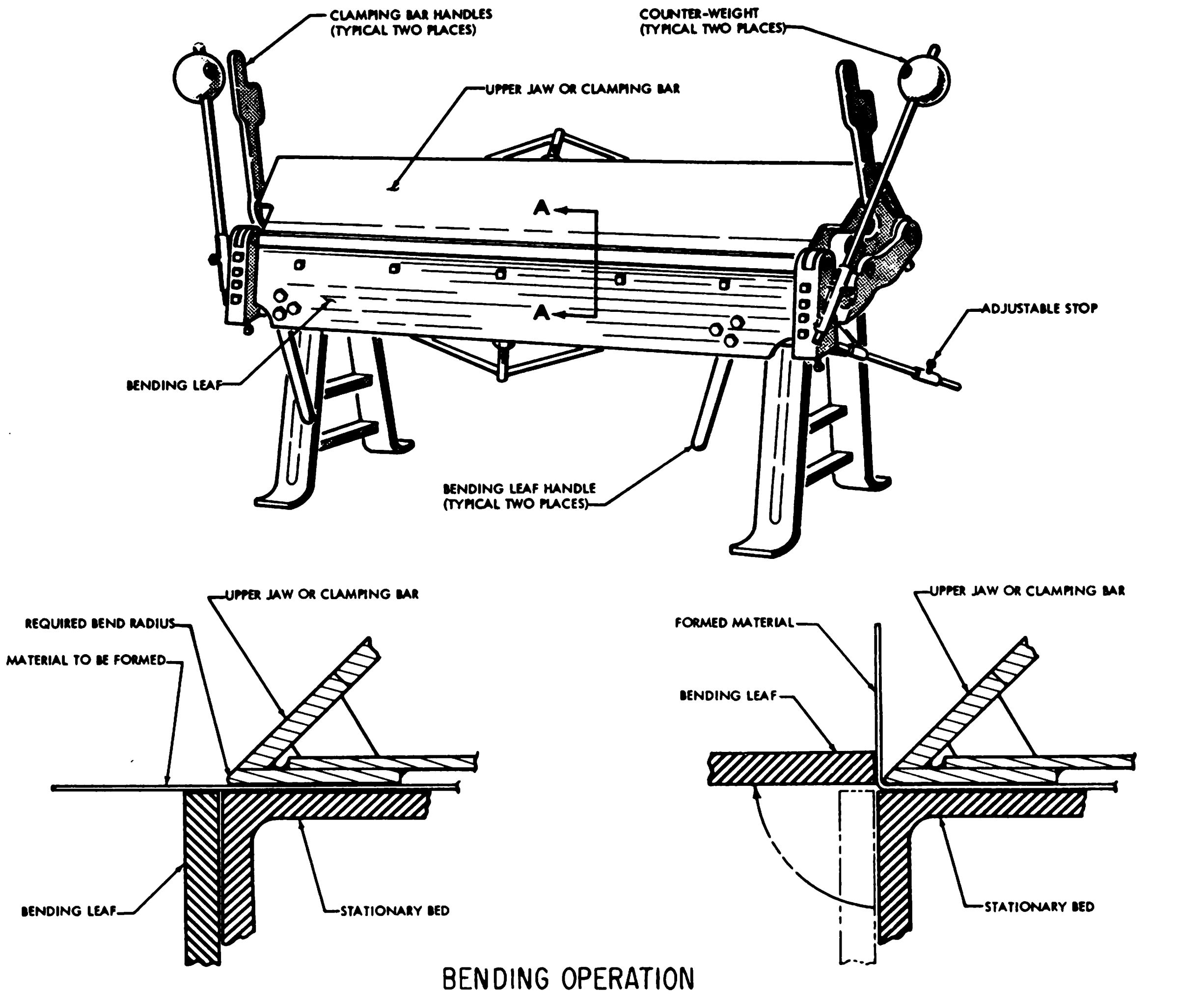
The finger brake is particularly useful in the forming of boxes, pans, and other similar shapes. If these shapes were formed on a cornice brake, one would have to straighten part of the bend on one side of the box in order to make the last bend. In the finger brake, simply remove the fingers that are in the way and use only the fingers required to make the bend.

The fingers are secured to the upper leaf by thumbscrews, as shown in figure 6-22. All fingers which are not removed for any operation must be securely seated and firmly tightened before the brake is used.

To keep brakes in good condition, keep the working parts well oiled and be sure that the jaws are free of rust and dirt. In operating the brakes, take care to avoid doing anything that would spring the parts, force them out of alignment, or otherwise damage them. Never use brakes for bending metal that is beyond their capacity as to thickness, shape, or type. Never try to bend rod, wire, strap iron, or spring steel sheets in a brake. If it is necessary to hammer the work, take it out of the brake first.

Bending on Bar Folder

The bar folder may be used to bend and fold metal in a number of different shapes, as illustrated in figure 6-23. This machine has two adjustments, one for regulating the width of the fold and the other to provide sharp or rounded bends. To operate the bar folder, adjust the thumbscrew to the specified width of the fold then turn the adjusting knob on the back of the machine for the desired sharpness of the bend. Insert the metal under the folding blade until it rests against the stops. Hold the metal firmly in place with one hand, grasp the handle with the other, and pull forward until the desired fold is made. The necessary steps in making a single hem are illustrated in figure 6-24.



AM.276

Figure 6-19.—Cornice brake and operation.

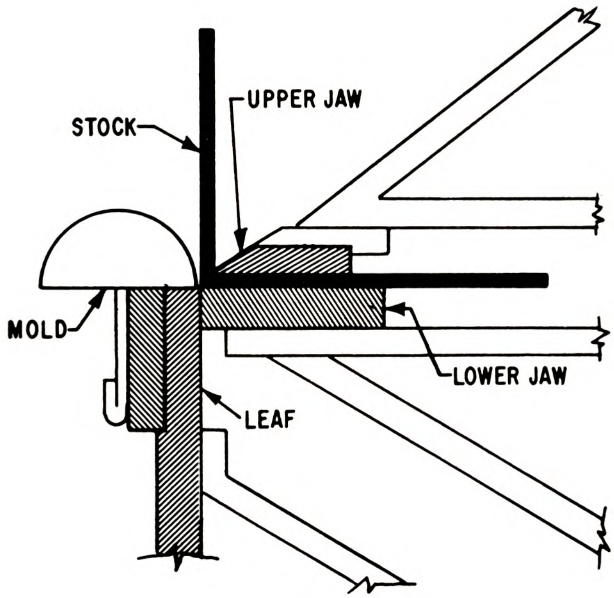
SHEET METAL EDGES AND SEAMS

In most cases, the edges of finished sheet metal parts are reinforced in some way. This not only strengthens the edges but also serves to protect against possible cuts and other injuries to personnel who must handle and/or work around these structural parts. There are also different types of seams used to join sheets of metal. Some of the most common methods used to reinforce the edges of sheet metal and the most common types of seams used in sheet metal work are discussed in the following paragraphs.

Reinforced Edges

There are several different methods used to reinforce or stiffen the edges of sheet metal. One method is to form either a single or double hem; another is to reinforce the edge with a wire or rod.

A single hem is formed by simply turning the metal back on itself once, as shown in figure



AM.277
Figure 6-20.—Cornice brake with mold and stock.

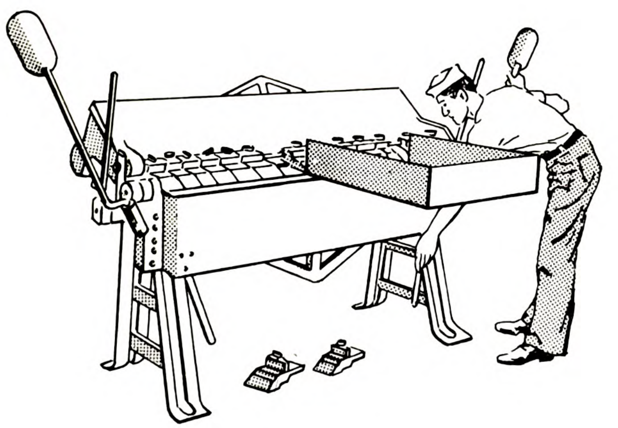


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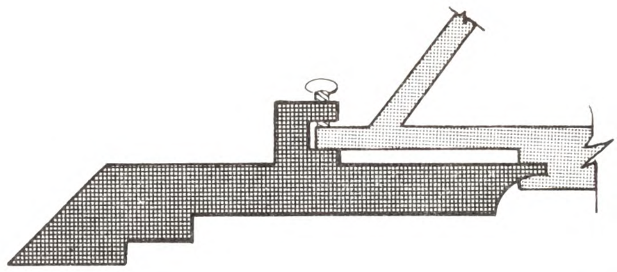
Figure 6-21.—Box and pan brake being used to form box.

6-25. A double hem, also shown in the illustration, is formed in the same manner, except that the metal is folded twice instead of once.



AM.279
Figure 6-22.—Finger secured in box and pan brake.

A wire edge is made by wrapping the metal around a piece of wire or rod, the metal being bent by hand or on a bar folder. An allowance equal to two and one-half times the diameter of the wire should be provided for the fold to receive the wire. Figure 6-26 shows a wire edge being formed by hand although a much more workmanlike job is accomplished by using the rotary machine illustrated in figure 6-12. The final wrapping operation may be continued either with the peen of a hammer or with a wiring machine.

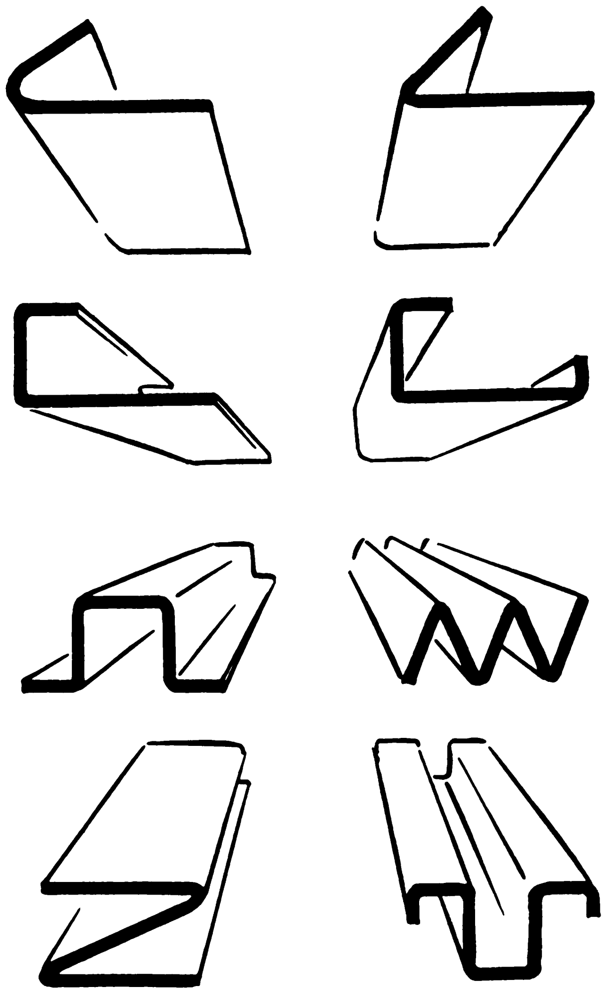
Sheet Metal Seams

The place where two sheets of metal are joined together is called a seam. The three most common types of seams used in sheet metal work are the lap seam, the grooved seam, and the standing seam.

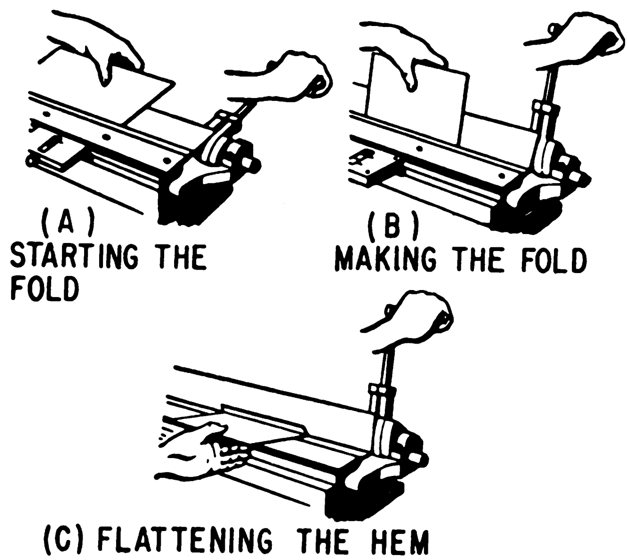
The lap seam is the least difficult to fabricate. In making this seam, the pieces of stock are merely lapped one over the other and secured by riveting or soldering, or both, the method used depending upon the degree of structural strength required and whether or not a watertight seam is required.

A grooved seam is used in the construction of cylindrical objects, such as funnels, pipe sections, containers, marking buoys, and tanks. The steps in forming a grooved seam are shown in figure 6-27. Step (C) is accomplished with either a hand or a machine groover.

The standing seam is frequently used when joining two sections or parts of an object, such as the splash ring to the body of a funnel. The steps in making a standing seam are shown in figure 6-28. If the object has straight sides,



AM.280
Figure 6-23.—Types of bends made on a bar folder.



AM.281
Figure 6-24.—Bar folding a single hem.

AM.282
Figure 6-25.—Single and double hems.

the flanges may be turned in the bar folder; and if cylindrical, the flanges are turned on the burring machine. Notice the distribution of the allowance for the seam. Two-thirds of it is on one section, the remaining portion on the other. Sections A and B are equal, and C is one thickness of the metal less than A.

LAYOUT PRACTICES

In laying out metal prior to bending it to a desired shape, there are certain precautions which should be observed. In the following paragraphs are some of the more important precautions; for information on the use of layout tools and layout procedures in general, refer to Tools and Their Uses, NavPers 10085-B.

Every precaution must be taken to avoid marring aluminum-alloy sheet, and even steel sheet should be carefully handled. To protect the under surface of the material from any possible damage, it is often advisable to place a piece of heavy paper, felt, or plywood between the material and the working surface. In working with a large sheet of material, it is important to avoid bending it; hence, it is a good idea to have a helper in placing it on the working surface.

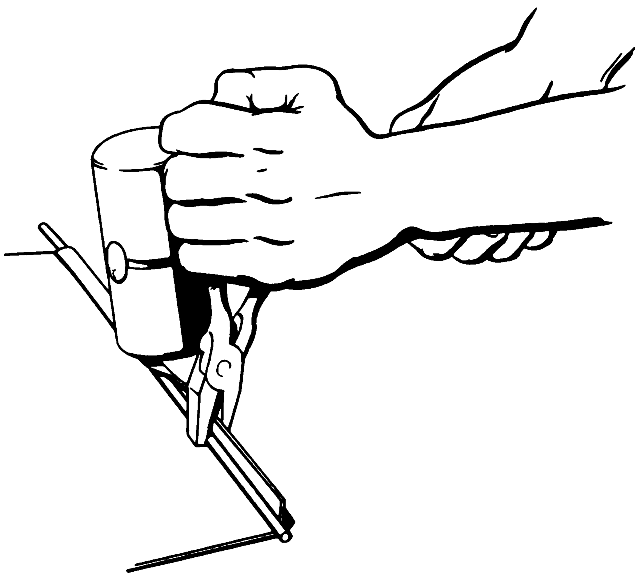


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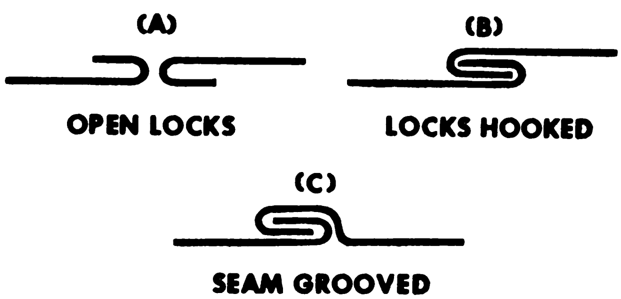
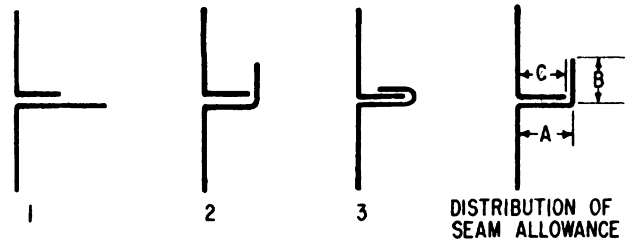
Figure 6-26.—Hand forming a wire edge.



AM.284
Figure 6-27.—Forming a grooved seam.

A layout fluid should be applied to the surface of the metal so that the pattern will stand out clearly. Any one of several approved fluids may be used. Zinc chromate and bluing fluid are two of the most commonly used. Since zinc chromate protects a metal surface against corrosion and also serves as a base for paint, it need not be removed after the layout is completed. Bluing fluid is merely a blue dye dissolved in alcohol. It does not protect metal



AM.285
Figure 6-28.—Steps in forming a standing seam.

against corrosion or serve as a paint binder, so it should be removed either with ordinary paint thinner or with alcohol.

To begin the layout, one edge of the metal should be straight. Use the squaring shears if necessary, then test the job with a straightedge. All measurements can then be based on the straight edge of the sheet. Lines at a known angle or parallel to the straight edge can be made by marking off points from a combination square held firmly against the straight edge.

If it is impossible to obtain a straight edge on a sheet to start a layout, or if the distance from the edge is too great, a reference line may be used. The reference line may be made by connecting any two points with a straight line. Perpendiculars may be erected to the reference line by using a compass or dividers, thus forming a cross. Once the cross is accurately laid out, it may be used as a basis for almost any type of fitting layout.

A scriber must never be used for drawing lines on aluminum or magnesium except to indicate where the metal is to be cut or drilled. All other lines must be drawn with a soft-lead pencil. Folding a piece of metal along a sharp line made with a scriber will weaken the metal and possibly cause it to crack along the bend. If it does not crack at the time of bending, it is very susceptible to cracking in service, possibly at a time when failure of the part can be catastrophic.

DRILLING

During the fabrication and repair of structural parts, the ASH must drill holes in the metal for insertion of rivets, bolts, and other

types of fasteners. In some instances this can be accomplished in the shop with the use of a stationary drill press. However, much of this type work must be accomplished on the item of support equipment; therefore, some type of portable drill must be used.

There are two major types of drill presses—the bench type and the upright type. Information concerning these types of drill presses is covered in Tools and Their Uses, NavPers 10085-B, and is therefore not repeated here.

The three major types of portable drills are the hand drill, the electric drill, and the pneumatic drill. These are also covered in Tools and Their Uses. Additional information concerning the use of portable drills is covered in chapter 10 of this manual. The types and selection of twist drills for use with stationary or portable drills are also covered in Tools and Their Uses. Additional information concerning twist drills is presented in chapters 5 and 10 of this manual.

CHAPTER 7

OXYACETYLENE WELDING, BRAZING, AND SOLDERING

Welding is the most practical of the many metal joining processes available to manufacturers of ground support equipment. The welded joint offers rigidity, simplicity, low weight, high strength, and low cost production equipment. Consequently, welding has been universally adopted in the building of many items of support equipment. Many structural parts are joined by some form of welding, and the repair of these parts is an indispensable part of the maintenance of support equipment.

The term welding refers to a metal-joining process in which fusion into one body is produced by heating to suitable temperatures, with or without the application of pressure, and with or without the use of filler metal. There are eight principal groups of welding processes—arc, gas, resistance, brazing, thermit, forge, flow, and induction. Considering the subdivisions of these main groups, however, there are more than 35 distinct welding processes.

Welding processes obviously have differences which distinguish one from another. However, all welding processes are based upon the principle of applying or generating heat at the joint and bringing the surfaces into intimate contact so that the joining surfaces will combine into one body. Although combining of the joining surfaces is the goal of all welding processes, this goal is achieved in different ways.

With respect to heat, the welding processes differ as to the source of heat, the manner in which heat is applied or generated, and in the intensity of the heat. The source of heat may be the combustion of a fuel gas such as acetylene in combination with oxygen; an electric arc; an electric, gas, or oil furnace; the resistance of metal to the flow of electric current; or chemical reaction between a metal and finely divided aluminum.

The welding processes most commonly used by an ASH involve the combustion of a fuel gas, as in oxyacetylene welding, and the use of an electric arc, as in metallic arc and inert-gas shielded arc welding. Electric (metallic) arc and inert-gas shielded arc welding arc covered in chapters 8 and 9, respectively. The remainder of this chapter is devoted to oxyacetylene welding and cutting, brazing, and soldering.

OXYACETYLENE WELDING

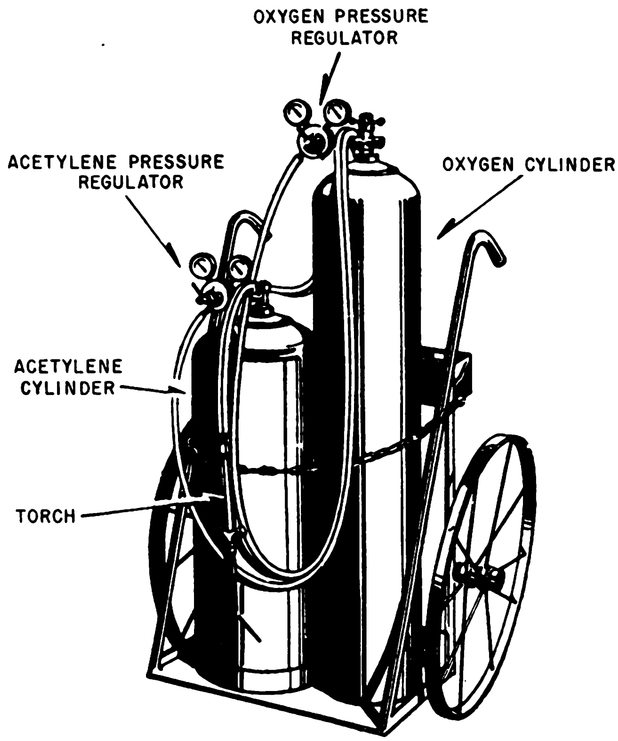
Gas welding is a fusion process in which heat is supplied by burning a mixture of oxygen and a suitable combustion gas, usually acetylene; hence, the term oxyacetylene. A welding torch is used to mix the gases in the proper proportions and to direct the flame against the parts to be welded. The molten edges of the parts then literally flow together and, after cooling, form one solid piece. Usually it is necessary to add extra material to the joint. The correct material in rod form is dipped in and fuses with the puddle of molten metal from the parent metal parts.

Acetylene is widely used as the combustible gas because of its high flame temperature when mixed with oxygen. The temperature, which ranges from approximately 5,700° to 6,300°F, is so far above the melting point of all commercial metals that it provides a means for the rapid localized melting essential in welding. The oxyacetylene flame is also used in cutting ferrous metals. The oxyacetylene welding and cutting methods are widely used by all types of maintenance activities because the flame is easy to regulate, the gases may be produced inexpensively, and the equipment can be transported easily and safely.

EQUIPMENT

Oxyacetylene welding equipment may be either stationary or portable. A portable outfit can be fastened on a hand truck and pushed around from job to job. It consists of two cylinders, one containing oxygen and one containing acetylene; acetylene and oxygen pressure regulators complete with pressure gages and connections; a welding torch with a mixing head,

extra tips, and connections; two lengths of colored hose, with adapter connections for the torch and regulators; a special wrench; a pair of welding goggles; a flint lighter; and a fire extinguisher. Figure 7-1 shows a portable outfit mounted on a hand truck.



AM.508

Figure 7-1.—Portable oxyacetylene welding outfit.

Stationary equipment is similar to a portable outfit except that the acetylene and oxygen are piped to several welding stations from a central supply. Master regulators are used to control the flow of gas and maintain a constant pressure at each station. This is known as a manifold system.

Oxygen

Oxygen is a colorless, tasteless, and odorless gas, slightly heavier than air. It will not burn by itself, but will support combustion by combining with other gases. This means that it aids in burning, and this burning gives off considerable heat and light. In its free state, oxygen is one of the most common elements. It makes up about 21 parts in 100 parts of air, while nitrogen accounts for 78 parts. Carbon dioxide and rare gases account for the remainder. It is the presence of oxygen in air that causes rusting of ferrous metals and the discoloration of copper and corrosion of aluminum. This action is known as oxidation. Oxygen unites with the acetylene gas in oxyacetylene welding, causing it to burn, and raising the temperature of the flame to the point where it will melt the metal.

Oxygen is obtained for commercial use by one of two methods: (1) It may be obtained by the liquid-air process, in which atmospheric air is compressed and cooled until it is in a liquid state. In this state the liquid is heated slightly and pure oxygen is distilled out and compressed in cylinders. (2) Oxygen may be produced by the electrolytic process, in which the hydrogen and oxygen in water are separated by passing a direct current through the water. Hydrogen gas is collected by means of an inverted container at the negative terminal, oxygen at the positive terminal, and each is then piped off and compressed in cylinders.

Oxygen produced for welding operations is called technical oxygen. However, aviator's breathing oxygen, which is specially produced for breathing purposes, may also be used. Because of the possibility of the two types being mixed aboard ship—with unpleasant results for the aviators—aircraft carriers and other ships using breathing oxygen carry only that kind, and it is also used for welding.

Oxygen Cylinders

Standard Navy oxygen cylinders used in welding operations are made of seamless steel and come in two sizes. The smaller size holds 200 to 220 cubic feet of oxygen at 1,800 to 2,015 pounds per square inch (psi) pressure; the larger size holds 250 cubic feet of oxygen at 2,265 psi pressure. All oxygen cylinders are painted green for identification. Technical oxygen cylinders are solid green; breathing oxygen cylinders have a white band around the top.

Each oxygen cylinder has a high-pressure valve located at the top of the cylinder. This valve is protected by a metal safety cap which should always be in place when the cylinder is not in use.

OXYGEN SHOULD NEVER BE BROUGHT IN CONTACT WITH OIL OR GREASE. In the presence of pure oxygen, these substances become highly combustible. Oxygen hose and valve fittings should never be oiled or greased or handled with oily or greasy hands. Even grease spots on clothing may flare up or explode if struck by a stream of oxygen. Beeswax is the recommended lubricant for oxygen equipment and fittings.

Acetylene Gas

Acetylene is a flammable, colorless gas. It has a distinctive disagreeable odor that is easily detected, even when the gas is greatly diluted with air. Unlike oxygen, acetylene does not exist free in the atmosphere; it must be manufactured. The process is neither difficult nor expensive. Calcium carbide is made to react chemically with water to produce acetylene.

The gas is either used directly in a manifold system or stored in cylinders. If it is ignited in this state, the result is a yellow, smoky flame with a low temperature. When the gas is mixed with oxygen in the proper proportions and ignited, the result is a blue-white flame with temperatures which range from approximately 5,700° to 6,300°F.

Under low pressure at normal temperatures, acetylene is a stable compound; but when compressed in an empty container to pressures greater than 15 psi, it becomes dangerously unstable. For this reason, manufacturers fill the acetylene cylinders with a porous substance (generally a mixture of asbestos and charcoal) and saturate this substance with acetone. Since acetone is capable of absorbing approximately 25 times its own volume of acetylene gas, a cylinder containing the correct amount of acetone can be charged to a pressure of 250 psi without fear of the acetylene becoming unstable.

Acetylene Safety Precautions

Acetylene safety precautions should be rigidly observed and enforced. Some of the more important things to remember are as follows:

1. Store acetylene cylinders in an upright position. They must be securely fastened to prevent shifting or falling under any circumstances. Do not lay on sides, drop, or handle roughly. If horizontal stowage is necessary, or an acetylene cylinder is inadvertently left lying in a horizontal position, it must be placed in an upright position for a minimum of 2 hours before using. (Otherwise, acetone in which the acetylene is dissolved will be drawn out with the gas.) Avoid damaging the valves or fuse plugs, since this causes leakage.
2. Store acetylene cylinders in a well-protected, well-ventilated, dry place, away from heating devices or combustible materials.
3. Use acetylene from cylinders only through pressure-reducing regulators. Do not use acetylene at pressures greater than 15 psi.
4. Open the acetylene valve slowly, 1/4 to 1/2 turn. This will permit an adequate flow of gas. Never open the valve more than 1 1/2 turns of the spindle. Use the special T-wrench provided, and leave it in place on the spindle so that the acetylene may be turned off quickly in an emergency.
5. Keep sparks, flames, and heat away from acetylene cylinders.
6. Turn the acetylene cylinder so that the valve outlet will point away from the oxygen cylinder.
7. Do not interchange hose, regulators, or other apparatus intended for oxygen with those intended for acetylene.
8. Use only approved hoses and fittings with acetylene equipment. Pure copper, or copper alloys containing 67 to 99 percent copper, must not be used in piping or fittings for handling acetylene (except blowpipe or torch tips). Acetylene reacts with pure or slightly alloyed copper to form cuprous acetylide, a violent explosive.
9. Test for leaks with soapy water—not with an open flame.
10. Make no attempt to transfer acetylene from one cylinder to another, refill an acetylene cylinder, or mix any other gas or gases with acetylene.
11. Keep valves closed on empty cylinders.
12. Should an acetylene cylinder catch fire, use a wet blanket to extinguish the fire. If this fails, spray a stream of water on the cylinder to keep it cool.
13. Crack each cylinder valve for an instant to blow dirt out of nozzles before attaching the pressure regulator. Do not stand in front of the valve when opening it.
14. Learn to identify standard Navy cylinders by color and decals.

Acetylene Cylinders

The standard Navy acetylene cylinder is a seamless steel shell with welded ends,

approximately 12 inches in diameter and 36 inches long. It is painted yellow and the name of the gas is indicated twice, once on each side of the cylinder, by 2-inch black letters painted lengthwise on the cylinder. A fully changed acetylene cylinder contains 225 cubic feet of gas at pressures up to 250 psi. In the event of fire or any excessive temperature rise, special safety fuse plugs installed in both the top and bottom of the cylinder melt, allowing the excess gas to escape or burn off, thereby minimizing the chances of an explosion. The holes in the safety plugs are made so small that they will not allow the flames to burn back into the cylinder. Acetylene cylinders should not be allowed to become completely empty, or a loss of filler material may result.

Pressure Regulators

Acetylene and oxygen regulators reduce pressures and control the flow of gases from the cylinders to the torch. Acetylene and oxygen regulators are of the same general type, although those designed for acetylene are not made to withstand such high pressures as are those designed for use with oxygen. The outlet fitting on acetylene regulators has left-hand threads to prevent interchange of hose.

In a portable welding outfit, such as that shown in figure 7-1, each regulator is equipped with two pressure gages—a high-pressure gage which indicates the cylinder pressure, and a low-pressure gage which indicates the pressure in the hose leading to the torch (working pressure).

In a stationary installation, where the gases are piped to individual welding stations, only one gage for oxygen and one for acetylene are required for each welding station, because it is only necessary to indicate the working pressure of the gases flowing through the hose to the torch.

A typical regulator, complete with pressure gages and connections, is shown in figure 7-2. The adjusting screw shown on the front of the regulator is for adjusting the working pressure. When this adjusting screw is turned to the left (counterclockwise) until it runs free, the valve mechanism inside the regulator is closed. No gas can then pass to the torch. As the handle is turned to the right (clockwise), the screw presses against the regulating mechanism, the valve opens, and gas passes to the torch at the pressure shown on the working pressure gage. Changes in this pressure may be made at will, simply by adjusting the handle until the desired pressure is registered.

Before opening the valve on a cylinder, the adjusting screw on the regulator should be fully released by turning to the left. As noted previously, this closes the valve inside the regulator, thus protecting the mechanism against possible damage.

Regulators are either single-stage or two-stage type. Single-stage regulators reduce the pressure of the gases from cylinder pressure to working pressure in one step or stage. In general, its mechanism consists of a floating valve, a diaphragm, and balancing springs.

In two-stage regulators, the pressure reduction is accomplished in two separate steps. This type of regulator has two independent diaphragm and valve assemblies which make operation extremely efficient. Pressure regulators are available in both the single- and two-stage type. The two-stage type is generally used with portable outfits.

Welding Torches

The welding torch is the unit used to mix the two gases in the proper proportions and to control the volume of the gases and the direction of the flame. The torch has two needle valves—one for adjusting the flow of oxygen, the other for adjusting the flow of acetylene. In addition, a handle, two tubes, a mixing head, and a tip are provided. Tips are interchangeable and come in various styles and sizes for welding a wide range of metal thicknesses.

Welding torches may be divided into two principal classes—the balanced-pressure type and the injector type. The balanced-pressure type is also referred to as the medium-pressure torch. The injector type is sometimes referred to as the low-pressure torch. Figure 7-3 shows the internal construction of the injector type torch.

In the balanced-pressure torch, the oxygen and acetylene are both fed to the torch at the same pressure. The openings to the mixing chamber for each gas are equal in size, and the delivery of each gas is independently controlled. This type of torch is generally better suited for most welding than the injector type because of the ease of adjustment and maintenance.

The injector type torch operates with an acetylene pressure of less than 1 psi and an

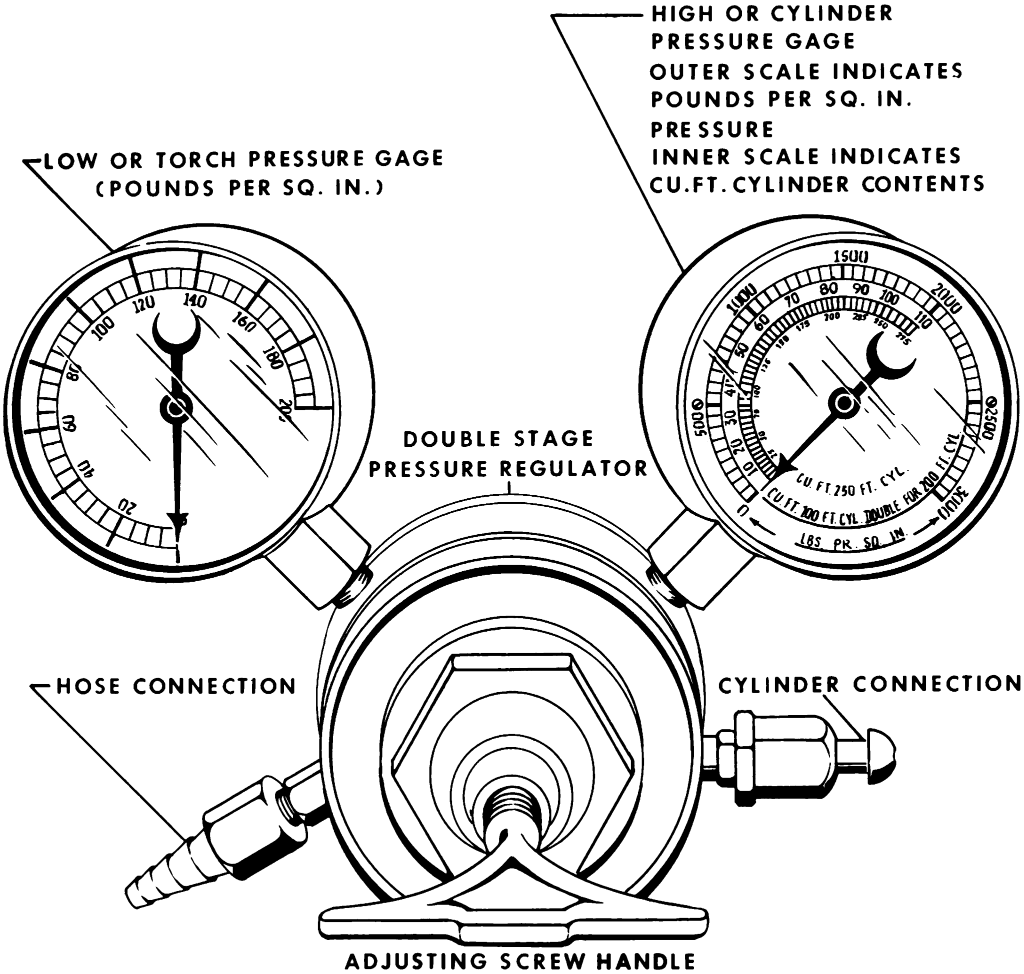


Figure 7-2.—Typical oxygen pressure regulator.

oxygen pressure from 10 to 40 times greater. In some welding torches of this type, the ratio of the pressure of the oxygen to the pressure of the acetylene is 20 to 1.

A narrow passageway or nozzle within the torch, called the injector, through which the oxygen passes, causes the speed of oxygen flow to increase to a high velocity with a corresponding drop in pressure. This drop across the injector creates a pressure differential (suction) which acts to draw the required amount of acetylene into the mixing chamber in the torch head.

TORCH TIPS.—The torch tip delivers and controls the final flow of gases. It is important that the correct tip be selected and used with the proper gas pressures if a job is to be satisfactorily welded. The nature of the weld, the material, the experience of the welder, and the position in which the weld is to be made, all determine the correct size of the tip opening. The size of the tip opening, in turn, determines the amount of heat (not the temperature) applied to the work. If a tip which is too small is used, the heat provided will be insufficient to produce penetration to the proper depth. If the tip is too

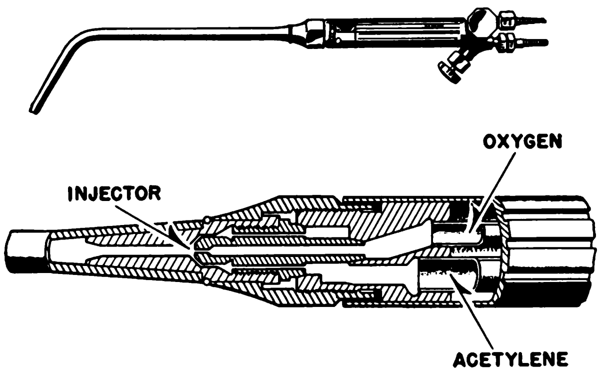


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Figure 7-3.—Welding torch.

large, the heat will be too great and holes will be burned in the metal.

There is no standard system for indicating the size of the opening in the torch tip; each manufacturer has his own numbering system. A comparison of the tips supplied by various manufacturers appears in table 7-1. The thickness of the metal for which each tip is adaptable is only approximate, since the nature of the weld, its position, and the conductivity of the metal are all factors in the selection of a torch tip. Such approximations may be used until the welder is experienced enough to know which size tip will produce the best weld for each situation.

With use, the torch tip will become clogged with carbon deposits and, if it is brought in

Table 7-1.—Torch tip sizes.

Tip size (inches)	Tip drill size	Smith tip No.	Victor tip No.	Airco tip No.	Approximate thickness of steel sheet
0.0200	76	--------	---------	---------	1/64 - 1/32
.0210	75	--------	000	00	1/64 - 1/32
.0225	74	100	---------	---------	1/64 - 1/32
.0250	72	--------	---------	0	1/32 - 3/32
.0260	71	101	---------	---------	1/64 - 3/64
.0280	70	--------	00	---------	1/64 - 3/64
.0292	69	102	---------	---------	1/16 - 1/8
.0310	68	--------	---------	1	1/16 - 1/8
.0320	67	103	---------	---------	1/32 - 5/64
.0350	65	--------	0	---------	1/32 - 5/64
.0370	63	104	---------	---------	3/32 - 5/32
.0380	62	--------	---------	2	3/32 - 5/32
.0400	60	--------	1	---------	3/64 - 3/32
.0430	57	105	---------	---------	1/16 - 1/8
.0465	56	106	2	3	1/8 - 3/16
.0550	54	107	---------	4	5/32 - 7/32
.0595	53	--------	3	---------	1/8 - 3/16
.0635	52	108	---------	---------	1/8 - 3/16
.0670	51	--------	---------	5	3/16 - 5/16
.0730	49	109	4	---------	3/16 - 1/4
.0760	48	--------	---------	6	1/4 - 3/8

contact with the molten pool, particles of slag may lodge in the opening. A split or distorted flame is an indication of a clogged tip. Tips should be cleaned with wire tip cleaners of the correct diameter or with soft copper wire. Tips should not be cleaned with drills or other hard, sharp instruments. These devices may enlarge or scratch the tip opening and greatly reduce the efficiency of the torch tip.

Fine steel wool may be used to remove oxides from the outside of the tip. These oxides hinder the heat dissipation and cause the tip to overheat.

Welding Hose

Welding hose used in connecting the cylinders with the torch are specially made for the purpose. Oxygen hose is either green or black, and acetylene hose is red or maroon. The hoses are attached to their respective regulators at one end and to the torch at the other. Acetylene hose fittings have left-hand threads and the nut is marked with a groove. Oxygen hose fittings have right-hand threads, and the nut is plain.

Lighters

A flint lighter is provided for igniting the torch. The lighter consists of a file-shaped piece of steel, usually recessed in a cuplike device, and a piece of flint that can be drawn across the steel, producing the sparks required to light the torch. CAUTION: Matches should never be used to ignite a torch; their length requires bringing the hand too close to the tip in order to ignite the gas. Accumulated gas may envelop the hand and, when ignited, cause a severe burn.

Goggles

Welding goggles are fitted with colored lenses to keep out heat and light rays and to protect the eyes from sparks and molten metal. Regardless of the shade of lens used, it should be protected by a clear cover glass. The welding operator should select the shade or density of color that is best suited to him for his particular work. The desired lens is the one of the darkest shade which will show a clear definition of the work without eyestrain. Goggles should fit closely around the eyes and should be worn at all times during welding and cutting operations.

Special goggles, utilizing standard lenses, are available for use with spectacles.

Welding (Filler) Rods

The use of the proper type filler rod is very important in oxyacetylene welding operations. This material not only adds reinforcement to the weld area, but also adds desired properties to the finished weld. By selecting the proper type rod, either tensile strength or ductility can be secured in a weld, or both can be secured to a reasonably high degree. Similarly, rods can be selected which will help retain the desired amount of corrosion resistance. In some cases, a suitable rod with a lower melting point will eliminate possible cracks from expansion and contraction.

Welding rods may be classified as ferrous and nonferrous. The ferrous rods include carbon and alloy steel rods as well as cast iron rods. Nonferrous rods include brazing and bronze rods, aluminum and aluminum alloy rods, magnesium and magnesium alloy rods, copper rods, and silver rods.

Welding rods are manufactured in standard 36-inch lengths and in diameters from 1/16 inch to 3/8 inch. The diameter of rod used is governed by the thickness of the metals being joined. If the rod is too small, it will not conduct heat away from the puddle rapidly enough, and a burned weld will result. A rod that is too large will chill the puddle. As in selecting the proper size welding torch tip, experience will enable the welder to select the proper diameter welding rod.

WELDING FLAMES

The welding flame is classified as neutral, oxidizing, or carburizing, each having its own special function. Adjustment of the torch enables the operator to produce the type of flame best suited for the job at hand.

The neutral flame, in which a balanced mixture of oxygen and acetylene is burned, is used for most welding operations. The oxidizing flame, in which an excess of oxygen is burned is used for welding bronze or fusing brass and bronze. The carburizing flame, in which an excess of acetylene is burned, is used when welding nickel alloys.

Neutral Flame

The neutral flame does not alter the composition of the base metal to any great extent and is therefore the best suited for most metals. The neutral flame burns at approximately 5,850°F. A balance mixture of one volume of oxygen and one volume of acetylene is supplied from the torch when the flame is adjusted to neutral.

As shown in figure 7-4. the neutral flame is divided into two distinct zones. The inner zone consists of the cone—a white, clearly defined, round, smooth cone, 1/16 to 3/4 inch in length.

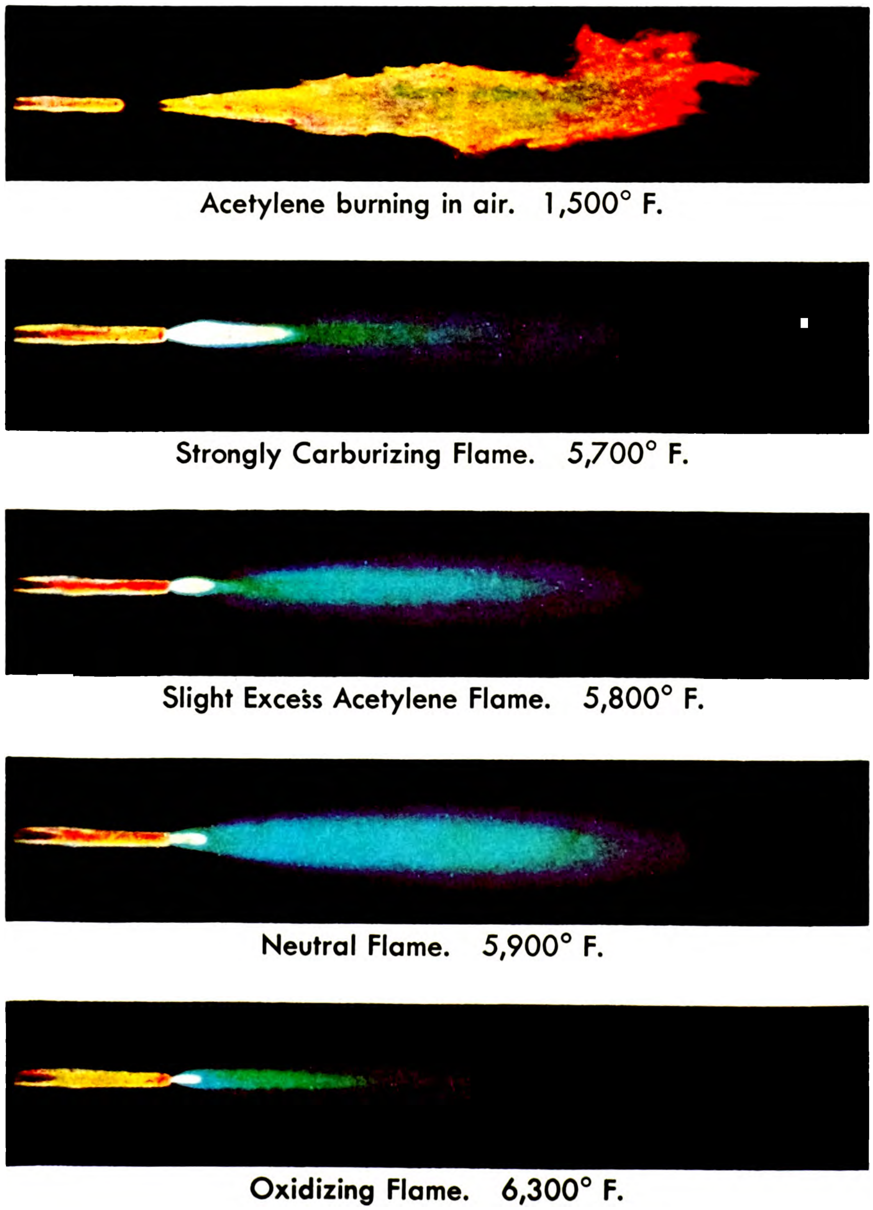

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Figure 7-4.—Characteristics of oxyacetylene flames. Courtesy of Air Reduction Sales Co.

The outer zone, made up of completely burned oxygen and acetylene, is blue with a purple tinge at the point and edges.

A neutral flame melts metal without changing its properties and leaves the metal clear and clean. If the mixture of oxygen and acetylene is correct, the neutral flame allows the molten metal to flow smoothly, and few sparks are produced when welding most metals.

Carburizing Flame

The carburizing flame, produced by burning an excess of acetylene, may be recognized by its three distinct colors. There is a bluish-white inner cone, a white intermediate cone, and a light-blue outer flame. It may be recognized also by the feather at the tip of the inner cone. (See fig. 7-4.) The degree of carburization can be judged by the length of the feather.

Oxidizing Flame

The oxidizing flame is produced by burning an excess of oxygen. It has the general appearance of the neutral flame, but the inner cone is shorter, slightly pointed, and has a purplish tinge. (See fig. 7-4.) This flame burns with a hissing sound. An oxidizing flame can be recognized when welding ferrous metals by the numerous sparks which are thrown off as the metal melts and by the foam or scum which forms on the surface.

Flame Adjustment

To adjust the flame, light the torch by opening the torch acetylene valve 1/4 to 1/2 turn. With only the acetylene valve open, the flame will be yellow in color and will give off smoke and soot.

Now open the torch oxygen valve slowly. The flame will gradually change in color from yellow to blue and will show the characteristics of the excess acetylene flame described earlier.

With most torches, there will still be a slight excess of acetylene when the oxygen and acetylene valves are wide open and the recommended pressures are being used. Now close the acetylene valve on the torch very slowly. It will be noticed that the secondary cone gets smaller until it finally disappears completely. Just at this point of complete disappearance the neutral flame is formed.

In order to see the effect of an excess of oxygen, close the acetylene valve still further. A change will be noted, although it is by no means as sharply defined as that between the neutral and excess acetylene flames. The entire flame will decrease in size, and the inner cone will become much less sharply defined.

Because of the difficulty in making a distinction between the excess oxygen and neutral flames, an adjustment of the flame to neutral should always be made from the excess acetylene side. Always adjust the flame first so that it shows the secondary cone characteristic of excess acetylene, then, increase the flow of oxygen until this secondary cone just disappears.

During actual welding operations, where a neutral flame is essential, the flame should be checked occasionally to make certain it is neutral. This is accomplished by momentarily withdrawing the torch from the work and increasing the amount of acetylene until a distinctive feathery edge appears on the inner cone. Then, slowly decrease the amount of acetylene until a well-defined cone, characteristic of the neutral flame, is formed.

With each size of tip, a neutral, oxidizing, or carburizing flame can be obtained. It is also possible to obtain a "harsh" or "soft" flame by increasing or decreasing the pressure of both gases.

For most regulator settings the gases are expelled from the torch tip at a relatively high velocity, and the flame is called "harsh." For some work it is desirable to have a "soft" or low velocity flame without a reduction in thermal output. This may be achieved by using a larger tip and closing the gas needle valves until the neutral flame is quiet and steady. It is especially desirable to use a soft flame when welding aluminum, to avoid blowing holes in the metal when the puddle is formed.

BACKFIRE AND FLASHBACK

Improper handling of the torch may cause the flame to backfire or, in very rare cases, to flashback. A backfire is a momentary backward flow of the gases at the torch tip, causing the flame to go out. Sometimes the flame may immediately come on again, but a backfire is always accompanied by a snapping or popping noise. A backfire may be caused by touching the tip against the work, by overheating the tip, by operating the torch at other than recommend pressures, by a loose tip or head, or

by dirt or slag in the end of the tip. A backfire is rarely dangerous, but the molten metal may be splattered when the flame pops.

A flashback is the burning of the gases within the torch and is dangerous. It is usually caused by loose connections, improper pressures, or overheating of the torch. A shrill hissing or squealing noise accompanies a flashback; and unless the gases are turned off immediately, the flame may burn back through the hose and regulators and cause great damage. The cause of a flashback should always be determined and the trouble remedied before relighting the torch.

SETTING UP EQUIPMENT

Setting up welding equipment and preparing for welding must be done systematically and in a definite order to avoid costly mistakes. Follow the instructions listed below, in the order given, to assure your own safety and the safety of the equipment.

1. Secure the cylinders so they cannot be upset. Remove the protecting caps from the cylinders, then the outlet connection caps.
2. Crack the cylinder valves by opening each valve for an instant to blow it out clean. Close the valves and wipe off the connections with a clean cloth.
3. Connect the acetylene pressure regulator to the acetylene cylinder and the oxygen regulator to the oxygen cylinder. Use a regulator wrench and tighten the connecting nuts tight enough to prevent leakage.
4. Connect the red (or maroon) hose to the acetylene pressure regulator and the green (or black) hose to the oxygen regulator. Tighten the connecting nuts tight enough to prevent leaks. (Notice the left-hand threads on the acetylene nose connections. Do not force, as these threads are made of brass and are easily damaged.
5. Release both pressure regulator adjusting screws by turning the adjusting screw handle on each regulator counterclockwise until it runs free. (This is to avoid damage to the regulators and pressure gages when the cylinder valves are opened.)
6. Open the cylinder valves slowly and read each of the cylinder pressure gages to check the contents in each cylinder. CAUTION: Stand to one side of the regulator while opening a cylinder valve to avoid possible injury.
7. Blow out each hose by turning the pressure adjusting screw handle inward (clockwise) and then turning it out again. CAUTION: Acetylene hose should be blown out only in a well-ventilated space, free from sparks, flame, or other sources of ignition.
8. Connect both hoses to the torch and check the connections for leaks by turning the pressure regulator screws in, with the torch needle valves closed. When 20 psi shows on the oxygen working pressure gage and 5 psi on the acetylene gage, close the valves by turning the pressure regulator screws out. A drop in pressure on the working gage indicates a leak between the regulator and torch tip. A general tightening of all connections should remedy the situation. If it becomes necessary to locate the leak, use the soapsuds method. Do this by painting all fittings and connections with a thick solution of soapy water.

   CAUTION: Do not hunt for an acetylene leak with a flame as a serious explosion can occur in the hose or in the cylinder.
9. Adjust the working pressure on both the oxygen and acetylene regulators by turning the pressure adjusting screw on the regulator clockwise until the desired settings are obtained.
10. Light the torch, using the friction lighter provided. The torch is lighted by opening the acetylene needle valve and igniting the acetylene as it leaves the torch tip. Adjust the flame for the welding operation at hand, as described earlier. CAUTION: When lighting the torch, always point the tip AWAY from your body, other persons, and flammable materials.

SHUTTING DOWN

Extinguish the torch flame by closing the acetylene needle valve first, then close the oxygen needle valve.

When welding is stopped and will not be resumed within 15 minutes, or when the equipment is to be left unattended for any period of time, the equipment must be secured as follows:

1. Extinguish the torch as described previously.
2. Close both acetylene and oxygen cylinder valves. (Leave regulators open momentarily.)
3. Open acetylene valve on torch and allow gas to escape (5-15 seconds) to outside atmosphere, NOT into small or closed compartment. Close valve.
4. Open oxygen valve on torch and allow gas in hose to escape (5-10 seconds). Close valve.
5. Close both regulators. NOTE: Regulators are closed when adjusting screws are

backed out (turned counterclockwise) until loose.

NOTE: This procedure for shutting down welding equipment is taken from NAVMAT P-5100, Safety Precautions for Shore Activities, and is therefore mandatory.

FUNDAMENTAL WELDING TECHNIQUES

The composition, thickness, shape, and position of the metal to be welded govern the techniques to be used. Techniques applying to the composition of the metal are covered later in this chapter. The fundamental techniques applying to different thicknesses, shapes, and positions of the metal to be welded are discussed in the following paragraphs.

Holding the Torch

The proper method to use in holding the torch depends upon the thickness of the metal being welded. For light gage metal, hold the torch as shown in figure 7-5, with the hose draped over the wrist. For heavier work, hold the torch as shown in figure 7-6.

Hold the torch so that the tip is in line with the joint to be welded, and inclined between 30 and 60 degrees from the perpendicular. The exact angle depends upon the type of weld to be made, the amount of preheating necessary, and the thickness and type of metal. The thicker the metal, the more nearly vertical the torch must be for proper heat penetration. The white cone of the flame should be held about 1/8 inch from the surface of the base metal.

If the torch is held in the correct position, a small puddle of molten metal will form. The puddle should be composed of equal parts of the two pieces being welded. After the puddle appears, begin the movement of the tip in a semicircular or circular motion. This movement assures an even distribution of heat on both pieces of metal. The speed and motion of the torch are learned only by practice and experience.

Forehand Welding

Forehand welding is the technique of pointing the torch flame forward in the direction in which the weld is progressing. The filler rod is added to the puddle as the edges of the joint melt before the flame. (See fig. 7-7.) The forehand method is used in welding most of the lighter tubings and sheet metals, or when the weld is to be made in certain positions.

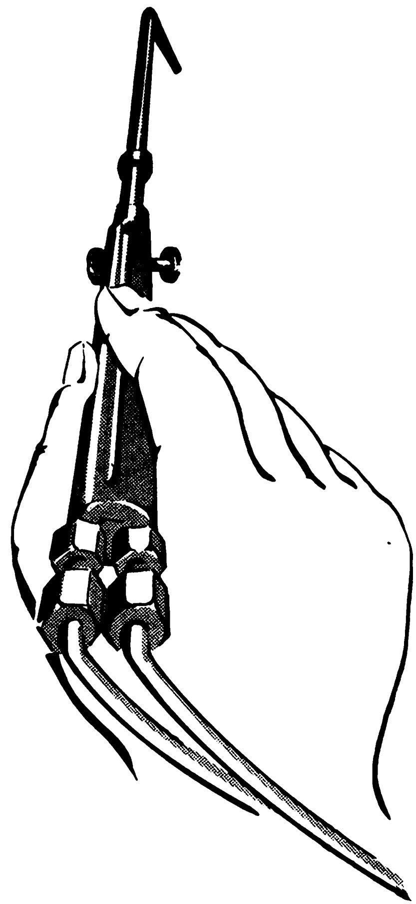

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Figure 7-5.—Welding light-gage metals.

Backhand Welding

Backhand welding is the technique of pointing the torch flame foward the finished weld and moving away in the direction of the unwelded area, melting the edges of the joint as it is moved. (See fig. 7-8). The welding rod is added to the puddle between the flame and the finished weld.

Backhand welding is seldom used on sheet metal because the increased heat generated in this method is likely to cause overheating and burning. It is preferred for metals having a thick cross section. The large puddle of molten

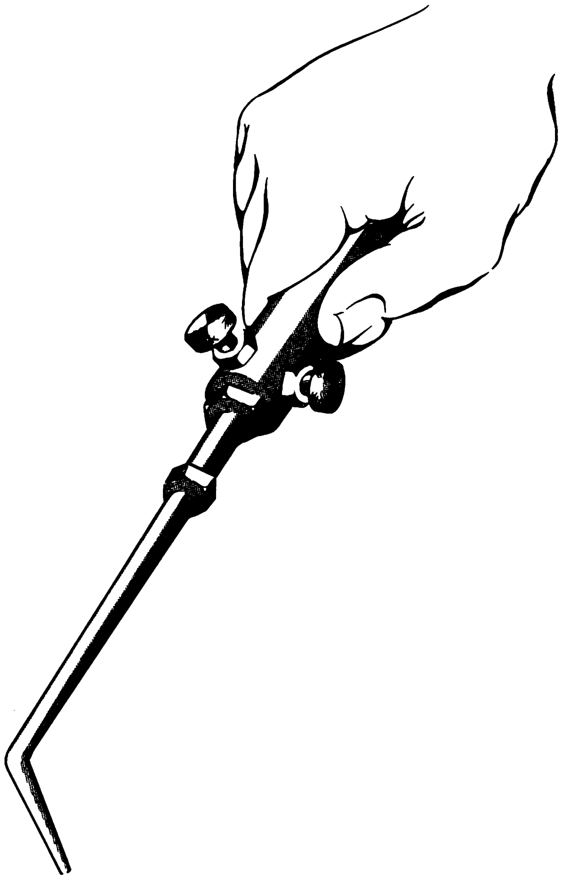

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Figure 7-6.—Welding heavy plate.

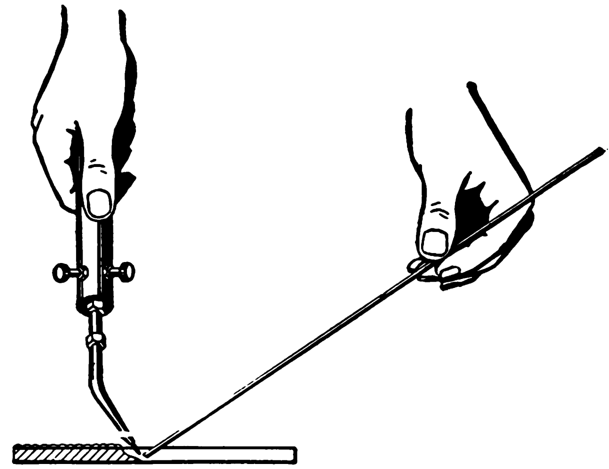

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Figure 7-7.—Forehand welding.

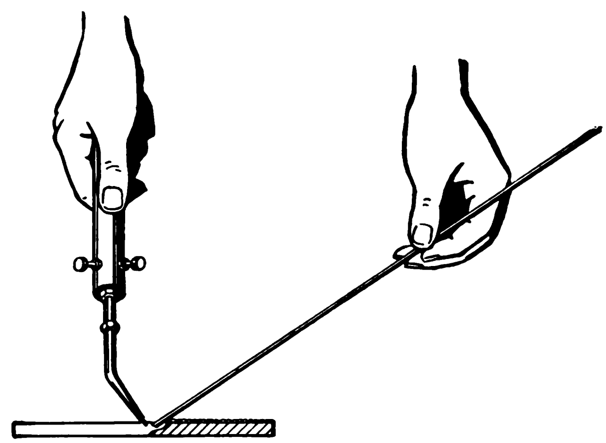

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Figure 7-8.—Backhand welding.

metal required for such welds is more easily controlled in backhand welding, and it is possible to examine the progress of the weld and determine if penetration is complete.

Welding Positions

The four basic welding positions are shown in figure 7-9. Also shown are four commonly used joints. Notice that the corner joint and butt joint are classified as groove welds, while the tee and lap joints are classified as fillet welds.

Welding is always done in the flat position whenever possible. The puddle is much easier to control, and the welder can work longer periods without tiring. Quite often though, it is necessary to weld in the overhead, vertical, or horizontal position in equipment repair.

The flat position is used when the material is to be laid flat or almost flat and welded on the topside. The welding torch is pointed downward toward the work. This weld may be made by either the forehand or backhand technique.

The overhead position is used when the material is to be welded on the underside with the torch pointed upward toward the work. In welding overhead, the puddle can be kept from sagging if it is not permitted to get too large or

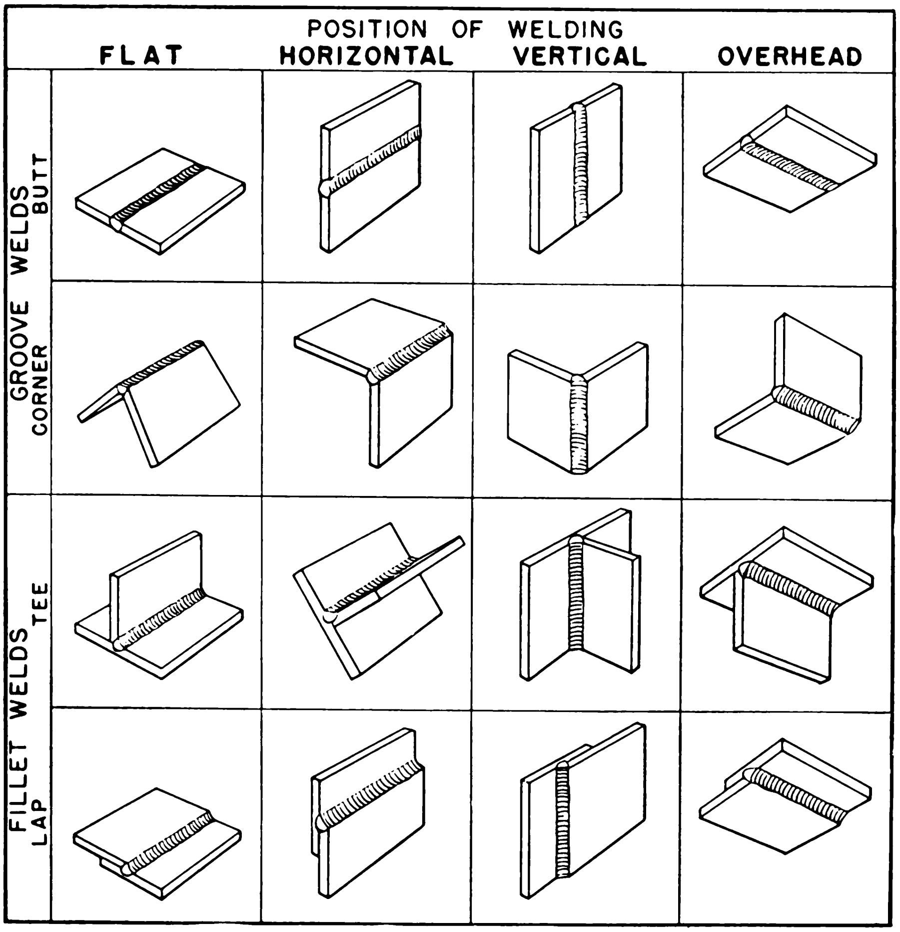

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Figure 7-9.—Four basic welding positions.

assume the form of a large drop. The rod is used to control the molten puddle. The volume of flame used should not be permitted to exceed that required to obtain a good fusion of the base metal with the filler rod. Less heat is required in an overhead weld because the heat naturally rises.

The horizontal position is used when the line of the weld runs horizontal across a piece of work, and the torch is directed at the material in a horizontal or near horizontal position. The weld is made from right to left across the plate (for the right-hand welder). The flame is inclined upward at an angle of from 45 to 60 degrees, and the weld is made with a normal forehand technique. Adding the rod to the top of the puddle will prevent the molten metal from sagging to the lower edge of the bead. If the puddle is to have the greatest possible cohesion, it should not be allowed to get too hot.

In a vertical weld, the pressure exerted by the torch flame must be relied upon to a great extent to support the puddle. It is highly important to keep the puddle from becoming too hot, in order to prevent the hot metal from running out of the puddle onto the finished weld. If may be necessary to remove the flame from the puddle for an instant to prevent overheating, and then return it to the puddle. Vertical welds are begun at the bottom, and the puddle is carried upward with a forehand motion. The tip should be inclined from 45 to 60 degrees, the

exact angle depending upon the desired balance between correct penetration and control of the puddle. The rod is added from the top and in front of the flame with a normal forehand technique.

WELDED JOINTS

The five fundamental types of welded joints are the butt joint, tee joint, lap joint, corner joint, and edge joint. (See fig. 7-10.)

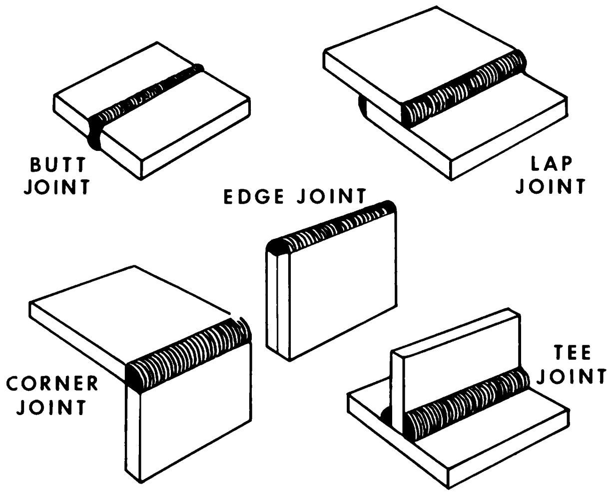

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Figure 7-10.—Types of welded joints.

Butt Joints

A butt joint is made by placing two pieces of material edge to edge, so that there is no overlapping, and then welding. Some of the various types of butt joints are shown in figure 7-11. The flanged butt joint is used in welding thin sheets, 1/16 inch or less. The edges are prepared for welding by turning up a flange equal to the thickness of the metal. This type is usually made without the use of filler rod.

A plain butt joint is used for metals from 1/16 to 1/8 inch in thickness. A filler rod is used in making this joint in order to obtain a strong weld.

If the metal is thicker than 1/8 inch, it is necessary to bevel the edges so that the heat from the torch can penetrate completely through the metal. These bevels may be either single or double bevel types or single or double

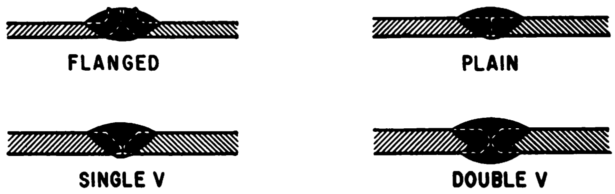

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Figure 7-11.—Types of butt joints.

V-type. The U-type joint is generally used on very thick metals. A filler rod is used to add strength and reinforcement to the weld.

Lap Joints

The lap joint is seldom used in oxyacetylene welding of flat stock, but is commonly used in spot welding. The single fillet lap joint, shown in figure 7-12, has very little resistance to bending, and will not withstand the shearing stress to which the weld is subjected under tension or compression loads.

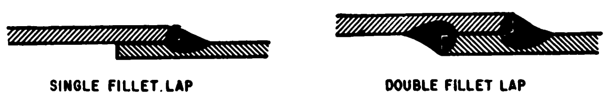

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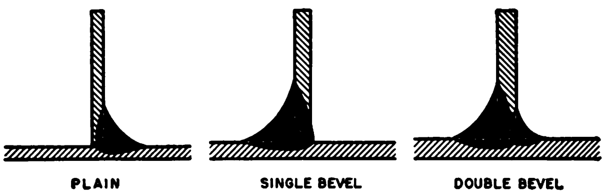
Figure 7-12.—Single and double fillet lap joints.

The double fillet lap joint, also shown in figure 7-12, offers more strength, but requires twice the amount of welding required on the simpler, more efficient butt weld.

Tee Joints

A tee joint is formed when the edge or end of one piece is welded to the surface of another, as shown in figure 7-13. These joints are quite common in tubular structures. The plain tee joint is suitable for thin plate metal but heavier metals require the vertical member to be single



AM.520
Figure 7-13.—Types of tee joints.

or double beveled, in order to permit the heat to penetrate deeply enough. The dark areas in the illustrations show the depth of heat penetration and fusion required.

Edge Joints

An edge joint may be used when two pieces of sheet metal must be fastened together and load stresses are not important. Edge joints are usually made by bending the edges of one or both parts upward, placing the two bent ends parallel to each other or placing one bent end parallel to the upright unbent end, and welding along the outside of the seam formed by the two joined edges. Figure 7-14 shows two types of edge joints. The type shown in (A) requires no filler rod, since the edges can be melted down to fill the seam. The type shown in (B) being thicker metal, must be beveled for heat penetration and filler rod added for reinforcement.

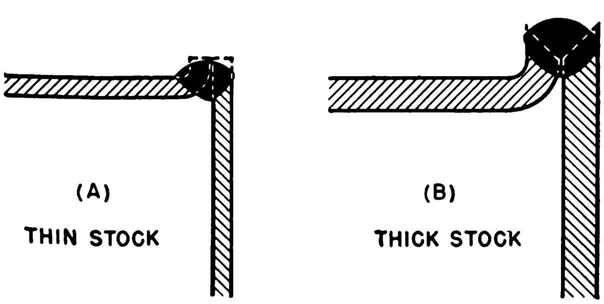


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Figure 7-14.—Types of edge joints.

Corner Joints

A corner joint is made when two pieces of metal are brought together so that their edges form a corner of a box or enclosure as shown in figure 7-15.

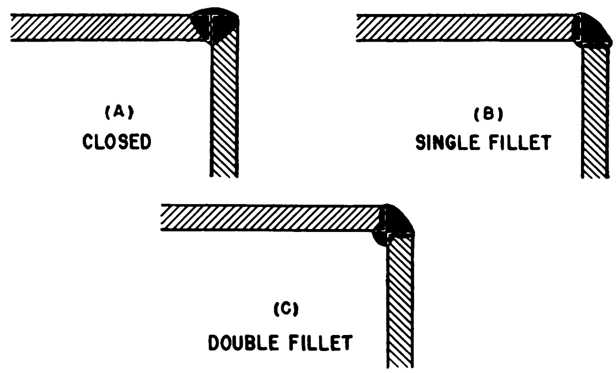

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Figure 7-15.—Types of corner joints.

The corner joint shown in (A) requires little or no filler rod, since the edges fuse to make the weld. It is used where load stress is unimportant. The joint shown in (B) is used on heavier metals, and filler rod is added for roundness and strength. If much stress is to be placed on the corner, the inside is reinforced as shown in (C).

MELTING POINT

The melting point of any substance is the temperature at which the solid substance becomes liquid. Pure metals have a constant melting point, but when alloyed with other metals or chemicals, the melting point is changed. The amount of the change depends upon the percentage and melting point of the alloying elements. A welder should know the approximate melting points of the various metals because it is often necessary to weld together metals which differ in this respect. Table 7-2 shows the melting point of the metals most commonly used in the manufacture of support equipment.

Table 7-2.—Melting points of metals.

Metal	Melting point (degrees F)
Aluminum, case, 8% copper	1,175
Aluminum, pure	1,220
Aluminum, 5% silicon	1,117
Bismuth	520
Brass	1,660
Bronze	1,598
Chromium	2,740
Copper	1,981
Inconel	2,540
Iron, cast	2,300
Iron, malleable	2,300
Iron, wrought	2,900
Lead	620
Magnesium	1,202
Molybdenum	4,532
Nickel	2,646
Silver	1,762
Steel, high carbon	2,500
Steel, low carbon	2,700
Steel, medium carbon	2,600
Steel, manganese	2,450
Steel, nickel	2,600
Steel, cast	2,600
Stainless steel	2,650
Tin	450
Titanium	3,100
Vanadium	3,182
Zinc, cast or rolled	786

EXPANSION AND CONTRACTION

Heat causes metals to expand; cooling causes them to contract. Uneven heating will, therefore, cause uneven expansion, or uneven cooling will cause uneven contraction. Under such conditions stresses are set up within the metal. These forces must be relieved, and unless precautions are taken, warping or buckling of the metal takes place. Likewise, on cooling, if nothing is done to take up the stress set up by the contraction forces, further warping may result; or if the surrounding cool sections of the metal are too heavy to permit this change in shape, the stresses remain within the metal itself. Such stresses may cause cracking while cooling, or may remain within the metal until further force is applied, as when the piece is put into use.

Sheet metal (1/8 inch and less in thickness) has such a large surface area per unit of weight, heat stresses tend to produce warping or buckling of the sheet. This and the contraction effect encountered on long seams are the main points to be considered in sheet metal welding.

The effect of welding a long seam (over 10 or 12 inches) is to draw the seam together as the weld progresses. If the edges of the seam are placed in contact with each other throughout their length before welding starts, the far ends of the seam will actually overlap before the weld is completed.

One way of overcoming this effect is illustrated in figure 7-16. The two pieces to be welded are placed with an increased allowance at the far end; and as the welding progresses, the two pieces are drawn together. This allowance is generally one metal thickness per foot of seam.

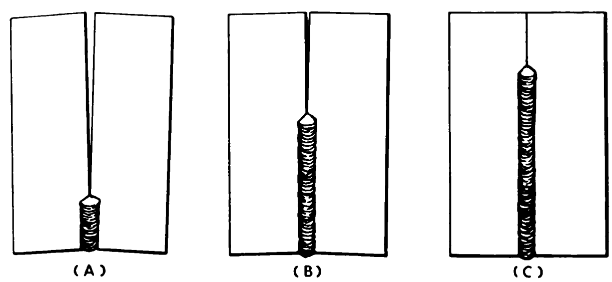

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Figure 7-16.—Allowance for straight butt weld.

Another method of controlling expansion and contraction is by the use of chill bars. Heavy pieces of metal are placed on either side of the weld; they absorb the heat and keep it from spreading across the whole surface area. Copper is commonly used for chill bars because of its ability to absorb heat readily. Welding jigs sometimes use this same principle to remove heat from the base metal. (See fig. 7-17.)

Preheating is another method of controlling expansion and contraction. Preheating is especially important in welding tubular structures and also in welding castings. Contraction still takes place at the weld, but there is also

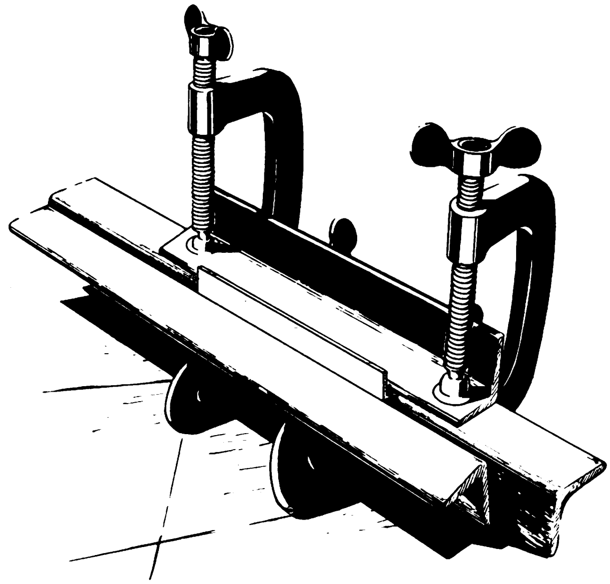

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Figure 7-17.—Example of the use of jigs and chill bars.

shrinking in the rest of the structure at approximately the same rate.

CHARACTERISTICS OF A GOOD WELD

A completed weld should have the following characteristics:

1. The seam should be smooth, the bead ripples evenly spaced, and of a uniform thickness.
2. The weld should be built up, thus providing extra thickness at the joint.
3. The weld should taper off smoothly into the base metal.
4. No oxide should be formed on the base metal close to the weld.
5. The weld should show no signs of blowholes, porousness, or projecting globules.
6. The base metal should show no signs of burns, pits, cracks, or distortion.

Although a clean, smooth weld is desirable, this characteristic does not necessarily mean that the weld is a good one; it may be dangerously weak inside. However, when a weld is rough, uneven, and pitted, it is almost always unsatisfactory inside. Welds should never be filed to give them a better appearance, since filing deprives the weld of part of its strength. Nor should they be filled with solder, brazing material, or filler of any sort.

When it is necessary to reweld a joint, all old weld material must be removed before the operation is begun. It must be remembered though, that reheating the area causes the base metal to lose its strength and become brittle.

WELDING FERROUS METALS

Low-carbon steel, low-alloy steel, cast steel, and wrought iron are easily welded with the oxyacetylene flame. Plain, low-carbon steel is the ferrous material that will be gas welded most frequently. As the carbon content of steel increases, welding becomes more difficult. For this reason parts made of steel may be repaired by welding only under certain conditions. Factors involved are carbon content and hardenability. For corrosion and heat resistant nickel-chromium steels, the allowed weldability depends upon their stability, carbon content, or reheat treatment.

Before attempting a repair which includes the welding of steels, the appropriate military specification should be consulted.

Preparation for Welding

Proper preparation for welding is an important factor in every welding operation. The edges of the parts must be prepared in accordance with the joint design chosen. The edges must be CLEAN. Arrangements must be made for holding the parts in proper alignment and for preheating, if this is required.

The first step in preparing a part for welding is to strip it of all dirt, grease or oil, and any protective coating such as cadmium plating, enamel, paint, or varnish. Such coatings not only hamper welding, but also mingle with the weld to prevent good fusion.

Cadmium plating can be chemically removed by dipping the edges to be welded in a mixture of 1 pound of ammonium nitrate and 1 gallon of water.

Enamel, paint, or varnish may be removed with a wire brush or emery cloth, by sandblasting, by using paint or varnish remover, or by treating the pieces with a 10 percent caustic soda solution followed by a thorough washing with hot water to remove the solvent or residue.

Sandblasting is the most effective method for removing rust or scale from steel parts. Grease or oil may be removed with a suitable grease solvent.

Welding Techniques

As stated previously, some types of ferrous metals are more difficult to weld than others. For this reason, the techniques used for welding these metals differ in some respects. Therefore, the techniques for welding various types of ferrous metals are covered separately in the following paragraphs.

CARBON STEELS.—In general, the carbon steels that are weldable require no preheating, and no flux is required. Use a low-carbon steel filler rod containing a small percentage of vanadium. Carefully adjust the torch flame to neutral.

Use the forehand method, holding the torch at an angle of 60 degrees to the surface of the work. Be sure that the tip of the inner cone of the flame does not quite touch the molten metal. If the edges of the metal have been beveled, use a swinging motion of the torch to melt the metal on each side of the groove.

While breaking down the edges, grasp the filler rod in the other hand and hold it in the outer cone of the flame to heat it. The filler rod should almost reach the melting point by the time that the puddle of molten metal has formed in the bottom of the groove.

Move the torch in one direction while moving the rod in the opposite direction. Dip the tip of the filler rod below the surface of the weld puddle just before the rod begins to melt, and move it from side to side in the puddle with a motion exactly opposite to the motion of the torch. If the filler rod is held above the surface of the puddle, it will melt and fall into the puddle a drop at a time. This ruins the weld.

Add filler metal until the surface of the joint is built up slightly above the edges of the parts being joined. Gradually advance the puddle of molten metal along the seam until the end is reached.

As the end of the seam is approached, raise the torch slightly, chilling the molten steel to prevent it from spilling over the edge and/or melting through the work.

CHROME-MOLYBDENUM STEEL.—The welding technique for chrome-molybdenum is practically the same as that for carbon steels, except that the surrounding area must be preheated to a temperature between 300° and 400°F before beginning to weld. To preheat the metal, direct the flame at such an angle that preheating takes place just ahead of the weld. Use a rod of the same material as the base metal. Use a soft neutral to slightly carburizing flame just large enough to melt the base metal and to obtain good fusion.

If jigs or fixtures are used, they should be designed to prevent any strains from contraction while the metal is cooling. In other words, the metal should not be clamped too tight.

Chrome-molybdenum thicker than 0.093 inch should be electric arc welded. In electric arc welding, the heat zone is narrower, the heat strains are lower, and a better weld will be obtained.

STAINLESS STEEL.—The procedure for welding stainless steel is basically the same as that for carbon steels. There are, however, some special precautions that must be taken in order to obtain the best results.

Only stainless steel used for nonstructural members can be welded satisfactorily; the stainless steel used for structural components is cold-worked or cold-rolled and, if heated, loses some of its strength. Nonstructural stainless steel is obtained in sheet and tubing form and is often used for exhaust collectors, stacks, or manifolds. Oxygen combines very readily with this metal in the molten state, and extreme care must be taken to prevent this combination.

A slightly carburizing flame is recommended for welding stainless steel, and the welder should adjust the flame so that a feather of excess acetylene, about 1/16-inch long, forms around the inner cone. Too much acetylene, however, will add carbon to the metal and cause it to lose its resistance to corrosion. The torch tip size should be one or two sizes smaller than that prescribed for a similar gage of plain steel. The smaller tip lessens the chances of overheating and subsequent loss of the "stainless" qualities of the metal.

Thin sheets which are to be butt welded should be tacked at intervals of 1 1/4 to 1 1/2 inches, as shown in figure 7-18. This is one means of lessening warping and distortion during the welding process.

Stainless steel must be protected from the atmosphere to prevent the nitrogen and oxygen in the air from combining with the hot metal. This is done by welding in an atmosphere of inert gas, or by using a suitable flux. Flux for gas welding of corrosion-resistant or heat-resistant alloys must conform to the requirements of Specification MIL-F-7516B. Fluxes must not increase the carbon content of the weld metal significantly.

The flux used with stainless steel is compounded especially to dissolve the chromium oxide which forms on the molten metal. It is mixed with water until it forms a thin paste. Apply the flux to the underside of the seam and to the filler rod. Allow the flux to dry a few minutes after brushing it on.

If the pieces to be welded are thinner than 0.063 inch, turn up flanges on each edge to a height equal to the metal thickness. The flanges

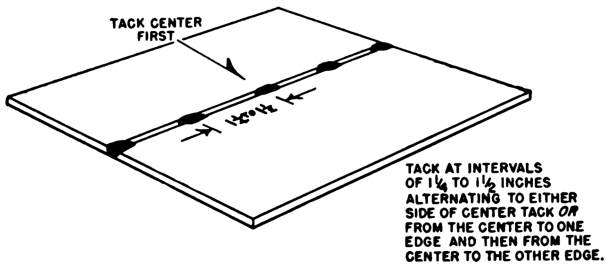

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Figure 7-18.—Tacking methods.

will melt down and furnish enough metal to fill the seam.

For stainless steel from 0.063 to 0.093 inch thick, use a plain butt joint and place a backing strip of copper beneath the seam to prevent the molten metal from flowing out of the weld and to absorb some of the heat. Use a filler rod of the same material as the base metal.

Stainless steel thicker than 0.093 inch should be electric arc welded if possible; but if it must be oxyacetylene welded, bevel the edges to form a V-type butt joint.

WELDING NONFERROUS METALS (ALUMINUM ALLOYS)

Gas welding of aluminum alloy is usually confined to materials from 0.031 to 0.125 inch in thickness. Thicker material may be gas welded if necessary, but thinner material is usually spot or seam welded.

Aluminum alloys best suited for gas welding are 1100, 3003, 5052, 6056, 6061, and 6063. Gas welding of 2014, 2017, 2024, and 7075 is not permitted, since the strength of the metal in the vicinity of the weld is lowered considerably and cannot be restored. Corrosion resistance is also seriously impaired.

Melting Characteristics of Aluminum

Before attempting to weld aluminum alloy for the first time, it is advisable to become familiar with the action of the metal under the welding flame.

Place a small piece of sheet aluminum on the welding table, light the torch, and adjust the flame to neutral. With the flame held perpendicular to the surface of the sheet, bring the tip of the inner cone almost in contact with the metal. Observe that almost without warning the metal suddenly melts and runs away leaving a hole in the sheet. Now repeat the operation with the torch held at an angle of about 30 degrees to the plane of the surface. With a little practice, you will be able to melt the surface metal without forming a hole. Now try moving the flame slowly along the surface of the sheet, melting a small puddle. Observe how quickly the puddle solidifies when the flame is removed. Continue this practice until able to control melting, then proceed with practice in actual welding, starting with simple flanged and notched butt joints which do not require welding rod. Then proceed with the use of welding rod, at first with thin sheet and subsequently with castings.

Preparation of Aluminum for Welding

Thickness of the material determines the method of edge preparation. On material up to 0.062 inch, the edges should be formed to a 90-degree flange about the same height as the thickness of the material or higher. (See (A) of fig. 7-19.) The only requirement for the flanges is that the edges be straight and square. If desired, material up to 0.125 inch may be welded with a flange type joint. No filler rod is necessary when the edges are flanged.

Unbeveled butt welds may be made on thicknesses from 0.062 to 0.188 inch, but in these applications it is necessary to notch the edges with a saw or cold chisel in a manner similar to that shown in (B) of figure 7-19. Edge notching is recommended in aluminum welding because it aids in getting full penetration and also prevents local distortion. All butt welds in material over 0.125 inch thick are generally notched in some manner.

In welding aluminum over 0.188 inch thick, bevel the edges and notch them as shown in (C) of figure 7-19. The included angle of bevel may be from 90 to 120 degrees.

After the edges of the pieces have been properly prepared, the surfaces to be welded

should be cleaned. If heavy oxide is present on the metal surface, it may be necessary to use a stainless steel wire brush. A solvent-soaked rag will remove dirt, grease, or oil.

PREHEATING.—Aluminum plate 1/4-inch thick and over should be preheated in order to prevent cracks and to assure more complete

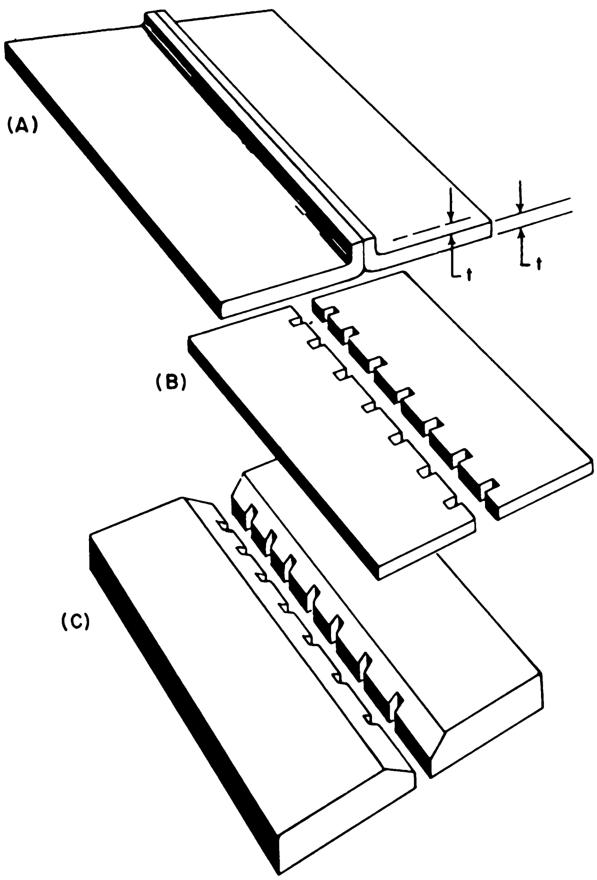

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Figure 7-19.—Edge preparation for gas welding aluminum.

penetration. Thin materials should be warmed with the torch prior to welding; even this slight preheat helps to prevent cracks.

WELDING RODS.—Two types of welding rods are available for gas welding aluminum alloys; they are the 1100 and 4043 rods. The 1100 rod is used when maximum resistance to corrosion and high ductility are of prime importance. The 1100 rod is used for welding 1100 and 3003 only. The 4043 rod is used for greater strength and to minimize the tendency for cracking. It is used for all other wrought aluminum alloys and may be used for castings.

WELDING FLUXES.—The use of the proper flux in welding aluminum is extremely important. Aluminum welding flux is designed to remove the aluminum oxide by chemically combining with it. In gas welding, the oxide forms rapidly in the molten metal. It must be removed or a defective weld will result. To insure proper distribution of the flux, it should be painted on the surface to be welded and also applied to the welding rod.

Aluminum flux is generally obtained in powder form and it should conform to Specification MIL-F-6939A. It is best prepared for use by mixing the powder with water to form a paste. The paste should be kept in an aluminum, glass, or earthenware container, since steel or copper containers tend to contaminate the mixture.

It is particularly essential that plenty of flux be applied to the edges of flanged joints since no filler rod is used in these joints. In all cases, the flux should be applied to both the bottom and top sides of the sheet in the area of the weld.

After welding is finished, it is important that all traces of flux be removed by using a brush and hot water. If aluminum flux is left on the weld, it will corrode the metal.

Welding Technique for Aluminum

After the pieces to be welded have been properly prepared and fluxed, pass the flame in small circles over the starting point until the flux melts. Then scrape the rod over the surface at about 3- or 4-second intervals permitting the rod to come clear of the flame each time, otherwise the rod will melt before the parent metal, and it will be difficult to note when the welding should start. The scraping action will reveal when welding can be started without overheating the aluminum. Maintain the same cycle throughout the course of welding except for allowing the rod to remain under the flame long enough to melt the amount of metal needed. The movement of the rod can easily be mastered with practice.

Forehand welding is generally considered best for the welding of aluminum alloys since the flame points away from the completed weld and thus preheats the edges to be welded. Too rapid melting is also prevented. Hold the torch at a low angle when welding thin material (less

than 30 degrees above horizontal). For thicknesses 0.188 inch and above, increase the angle of the torch to nearer vertical. Changing the angle of the torch in accordance with the thickness of the metal minimizes the possibility of burning through the sheet during welding.

In welding aluminum alloys up to 0.188 inch thick, there is little need to impart any motion to the torch other than moving it forward. On flanged material, care must be taken to break the oxide film as the flange melts down. This may be accomplished by stirring the melted flange with a puddling rod, illustrated in figure 7-20. (A puddling rod is essentially a paddle flattened and shaped from a 1/4-inch stainless steel welding rod.)

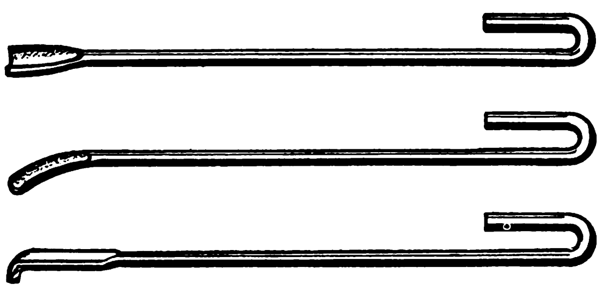

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Figure 7-20.—Puddling rods.

With aluminum alloys above 0.188 inch in thickness, the torch should be given a more uniform lateral motion to distribute the weld metal over the entire width of the weld. A slight back-and-forth motion will assist the flux in its removal of oxides. Dip the rod in the weld puddle periodically and withdraw it from the puddle with a forward motion.

The angle of the torch has much to do with welding speed. Instead of lifting the flame from time to time in order to avoid melting holes in the metal, it will be found advantageous to hold the torch at a flatter angle to the work. The speed of welding should be increased as the edge of the sheet is approached. The inner cone of the flame should never be permitted to come in contact with the molten metal, but should be held about 1/8 inch away from the metal.

In the vertical position, the torch is given an up-and-down rather than a rotating motion. In the overhead position, a light back-and-forth motion is employed the same as in flat welding.

Heat-treatable alloys should be held in a jig for welding, whenever possible. This helps to eliminate the possibility of cracking. The likelihood of cracking can also be reduced by the use of 4043 rod. This rod has a lower melting range than the alloy being joined and so permits the base metal to solidify before the weld puddle freezes. As the weld is the last area to solidify, all the contraction strains will be in the weld bead rather than throughout the base metal.

Cracking may also be reduced by tack welding the parts while they are in the jig and then loosening the clamps before completing the seam.

As soon as the weld is completed and the work has had time to cool, it should be washed thoroughly by vigorous scrubbing with a stiff brush and hot running water to remove all traces of flux. If left on the weld, it will corrode the metal. A diluted solution of 10 percent sulfuric acid may be used if hot water is not available. The acid solution should be washed off with cold fresh water after using.

CUTTING FERROUS METALS

There are numerous everyday uses for oxyacetylene flame cutting. It is a quick, inexpensive way to cut iron or steel where the effect of burning or heating the edge of a piece of metal is not objectionable.

Ferrous metals combine with oxygen so readily that the oxygen in the air can start the reaction, as rusty pieces of iron in scrap piles will attest. The rust is iron oxide, and the longer a piece is exposed to the elements, the more it is worn away and the more rust it collects.

Cutting iron or steel with an oxyacetylene torch is simply a speeding up of this process in a localized area, because iron oxidizes much more readily when it is hot. Pure oxygen, if directed on a hot piece of iron, increases the rate of oxidation so enormously that the metal is actually burned away.

The metal is heated to a bright red (1,400° to 1,600°F), which is the kindling or ignition temperature, and a jet of high-pressure oxygen is directed against it. This oxygen blast combines with the hot metal and forms an intensely hot oxide. The molten oxide is blown down the sides of the cut, heating the metal in its path to a kindling temperature. The metal thus heated also burns to an oxide which is blown away on the underside of the piece. This action is pre-

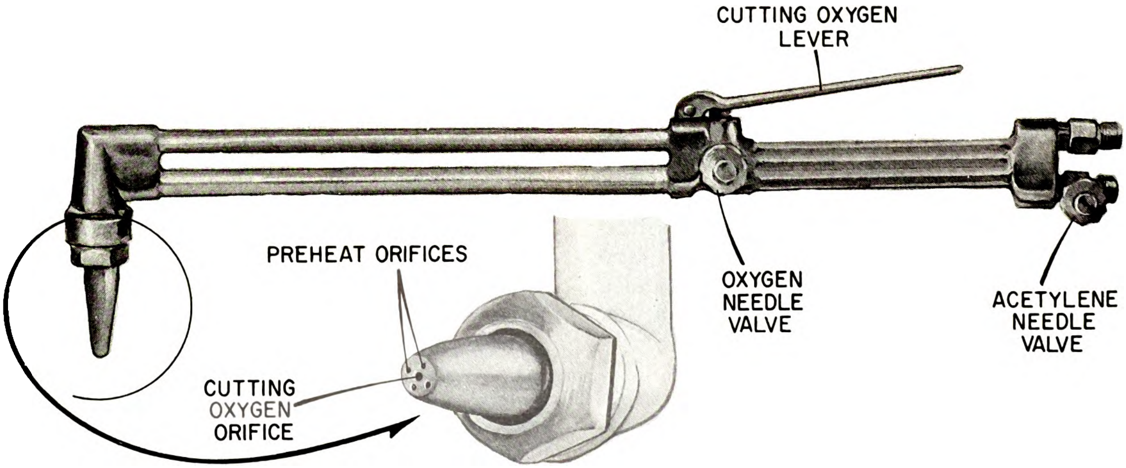

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Figure 7-21.—Cutting torch.

cisely that which the torch accomplishes when the mixing head is replaced with a cutting attachment or when a special cutting torch is used.

Figure 7-21 shows an example of a cutting torch. It has the conventional oxygen and acetylene needle valves, which control the flow of the two gases. Many cutting torches have two oxygen needle valves so a finer adjustment of the neutral flame can be obtained.

A cutting torch combines a heating flame with a jet of pure oxygen under pressure. The heating flame preheats the metal to a bright red, and the oxygen jet is directed upon the hot metal to burn it away and thus form a slit, known as a kerf, in the metal.

The heating flame in a cutting tip is generally not fed by a single hole as in a welding tip, but instead comes through several holes which are arranged in a ring around a larger central hole for oxygen. (See fig. 7-21.) The central oxygen tube tapers as it reaches the tip opening to increase the velocity.

The high-pressure cutting oxygen jet is regulated by an auxiliary oxygen control valve generally operated by a lever. This is shown in figure 7-21.

Four different size tips are generally supplied for cutting metals of varying thicknesses. There are also special tips for cleaning metal; cutting rusty, scaly, or painted surfaces; rivet cutting; and other special jobs.

Table 7-3.—Approximate pressure for various tip sizes.

Tip No.	Thickness of metal (inches)	Acetylene pressure (pounds)	Oxygen pressure (pounds)
1	1/8	4	10
1	1/4	4	15
1	3/8	4	20
1	1/2	4	25
2	3/4	5	30
2	1	5	40
2	1 1/2	5	50
2	2	5	60
3	3	6	70
3	4	6	80
3	5	6	90
4	6	7	100
4	8	7	130
4	10	8	160

In cutting, as in welding, the pressure of oxygen and acetylene and the size of tip are determined by the thickness and quality of the metal to be cut. Table 7-3 shows the approximate pressures for various size tips.

CUTTING PROCEDURE

Before beginning a cutting operation with an oxyacetylene cutting torch, a thorough inspection of the area should be made. There should be no combustible material which could be ignited by the sparks and slag produced by the cutting operation.

Insert the proper size tip in the cutting torch. Next, adjust the oxygen and acetylene pressures for the thickness of material to be cut. (The tip size and pressures should be in accordance with the cutting torch manufacturer's recommendations.) Put on goggles and gloves, then light the torch.

To light the torch, turn on the acetylene needle valve, light the gas, and adjust the flame to neutral as in welding. When the neutral flame is burning smoothly, actuation of the cutting oxygen control will disclose the type of cutting flame created. It may be necessary to readjust the neutral preheating flame while the control lever is depressed, to make sure that it remains neutral while cutting.

The line to be cut should be marked on the metal with soapstone or chalk. Then place the metal so that this line is beyond the end of the welding bench. If an exceptionally straight cut is desired, clamp a bar of steel across the piece of material to guide the torch.

Hold the torch in the right hand so that there is instant and positive control of the oxygen control lever. The left hand should be used to steady and guide the cutting torch. A fire brick or some other similar object placed on top of the material to be cut will provide a good rest for the left hand and help steady the torch. If the cutting tip wavers from side to side, a wide kerf will be made. This will result in a wide cut, slower speed, and greater oxygen consumption.

Begin cutting at the edge of the piece. (See fig. 7-22.) Hold the tip perpendicular to the surface of the metal, keeping the inner cone about 1/16 inch from the line. Hold the flame at this point until a spot in the metal turns bright red, then gradually depress the oxygen control lever. As soon as the cutting starts,

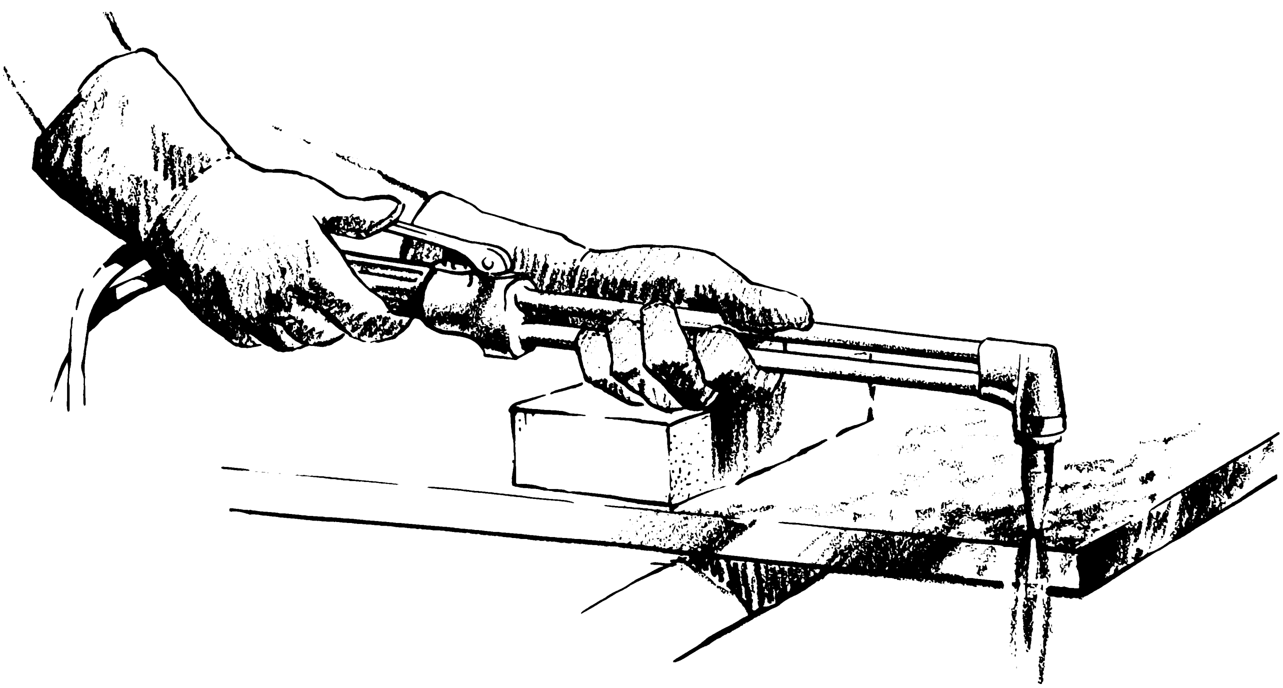

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Figure 7-22.—Starting the cut.

there will be a shower of sparks from the lower side of the material and the oxygen control lever should then be fully depressed.

When the cut has been started all the way through the material, move the torch slowly but steadily along the line. The motion of the cutting torch should be just fast enough so that the cut continues to penetrate completely without excessive oxidation or melting.

If the torch is moved too slowly, the heat from the preheating flame will tend to melt the edges of the cut, producing a ragged appearance or, at times, fusing the metal together again. On the other hand, if the torch is moved too rapidly, the cutting jet will fail to go through the material and cutting will be stopped. Should this happen, immediately release the lever, closing the cutting oxygen valve, and reheat at the point where the cutting stopped until it is a bright red. When the oxygen valve is reopened, the cutting will start again.

When the cut is finished, the cut section may stick to the main piece. This means that some of the slag produced by the cutting action has bridged across the bottom of the two pieces and on cooling has formed a thin crust which holds them together. The crust is quite brittle, however, and a smart blow from a hammer will break it and separate the pieces.

SAFETY PRECAUTIONS

1. Use no oil, grease, or any other lubricant on welding or cutting apparatus. Never allow oil or grease to come in contact with oxygen under pressure.
2. Always use the proper tip or nozzle, and operate it at the proper pressure for the particular work involved. This information should be taken from tables supplied with the equipment.
3. Do not experiment with or change regulators in any way. Always use regulators with the gas for which they were designed.
4. Do not use matches for lighting torches; a serious hand injury may result. Use friction lighters.
5. Do not light torches from hot metal, especially in a confined space. An explosive mixture of acetylene and oxygen in a confined space may cause damage or personal injury when ignited. Do not allow such a mixture to accumulate.
6. Always wear goggles when working with a lighted torch. Use only goggles designed specifically for welding use.
7. When extinguishing the torch, close the acetylene valve first, then close the oxygen valve.

BRAZING

Originally, brazing meant joining with brass, or "brassing." As the process was improved and new joining alloys were developed, the term assumed its present meaning—a group of thermal joining processes in which the bonding material is a nonferrous metal or alloy with a melting point higher than 800°F, but less than the metals being joined. Brazing, therefore, includes silver soldering, bronze welding, and hard soldering.

Brazing requires less heat than welding, and therefore may be used to join metals that are injured by high heat. The strength of brazed joints is not so great as welded joints however, and, for this reason, brazing is not used for critical structural repair on aircraft support equipment.

As the definition of brazing implies, the base metal parts are not melted. The brazing metal adheres to the base metal by molecular attraction and intergranular penetration; it does not fuse and amalgamate with them.

The usefulness of brazing is easily recognized when the many metals that can be joined by this process are considered. Brazing is applicable to the joining of cast iron, malleable iron, carbon steels, alloy steels, wrought iron, galvanized iron and steel, copper, and brass, bronze, and nickel alloys. It is also used to join dissimilar metals, such as cast iron to steel, or steel to copper.

Its principal use is in maintenance, making and repairing tools, jigs, and machinery. In this field it has many applications and attendant advantages. Among these are the relatively low temperatures involved, reduced chance of an excessively annealed area near the brazed joint, and the ability of a properly prepared brazed joint to stand heavy compression and impact loads.

BRAZING TECHNIQUE

In brazing a joint, first bevel down the edges as in welding steel. Clean the surrounding surfaces of dirt, rust, and so forth, then select the proper brazing alloy for the job.

The Navy supplies four brazing alloys which are graded A, B, C, and D. Grades A and B with melting points of about 1,600°F, are used for strong connections on steel, cast iron,

brass, bronze, and general brazing of nickel alloys. Grades C and D are suitable for brazing steel parts that are to be subjected to heat treatment under 1,600°F, after brazing. The melting point of grade C varies from 1,650° to 1,760°F, and that of grade D from 1,725° to 1,825°F.

Because of its higher melting point, grade D brazing alloy is more difficult to apply than grade C but is preferable with chrome-vanadium and chrome-molybdenum steel. When selecting a brazing alloy, choose one whose melting point is at least 100°F less than the metal being joined.

A brazing flux is necessary to obtain a good union between the base metal and the filler metal. A good flux for brazing steel is a mixture containing two parts borax and one part boric acid. Use a neutral torch flame and move it with a slight, semicircular motion.

Preheat the base metal slowly with a mild flame, and when it reaches a dull red heat (in the case of steel), heat the rod to a dark or purple color and dip it into the flux. Enough flux adheres to the rod and it is not necessary to spread it over the surface of the metal.

Bring the filler rod near the tip of the torch and let the molten bronze flow over a small area of the seam. The base metal must be at the flowing temperature of the filler metal before it will flow into the joint. The brazing metal melts when applied to the steel and runs into the joint by capillary attraction. Continue adding the rod, as the braze progresses, with a rhythmic dipping action so that the bead will be built to a uniform width and height. Complete the job rapidly and with as few passes of the rod and torch as possible.

The ideal brazing job is completed in one pass. Avoid multiple layers, and if the job requires more than one pass, always remove and replace the spent flux before applying succeeding layers of filler metal.

It is important that the brazing temperature be carefully controlled. If the base metal is heated excessively above the flow temperature of the brazing alloy, the bronze will boil when added and the low melting point alloys of the bronze will burn out, leaving the bronze porous and brittle. On the other hand, if the base metal is not hot enough, the bronze will not flow smoothly, but will form elusive drops which roll off as fast as the bronze is applied.

After finishing the job, allow it to cool slowly.

BRAZING CAST IRON TO STEEL

To braze cast iron to steel, flow molten bronze from a filler rod over the hot surface of the metal to be joined to obtain a solid bond between the edges of the seam.

Heat the work to be joined to a temperature slightly above the flow point of the brazing alloy. In the case of steel, this point is determined when the metal reaches a dull red color. Metals which lose their original qualities when melted can thus be joined by brazing without undergoing loss of those qualities.

Brazing is usually the best method of joining unlike metals (copper and steel) or two like pieces of a metal such as malleable cast iron which has been heat-treated.

Since the base metal is not melted in brazing, the joining process is greatly simplified. The preheating necessary in fusion welding is largely eliminated.

In deciding whether brazing of a joint is justified, remember that a metal which will be subjected to a sustained high temperature in use should not be brazed.

BRAZING BRASS

Brazing, rather than welding, is the most effective method of joining brass, because such technique requires a filler rod with a melting point slightly lower than the base metal. Thus, melting of the base metal is eliminated.

Brass, in its simplest form, is an alloy of copper and zinc, although other metallic elements are often added to improve its characteristics.

Naval brass, one of the best of these alloys, consists of 62 percent copper, 0.5 to 1.5 percent tin, 0 to 0.10 percent iron, 0.20 percent lead, and the remainder zinc. Its three advantages are high strength, toughness, and resistance to corrosion. It comes in bar, plate, rod, sheet, and strip form, and in soft, half-hard, and hard condition.

The torch flame with brass should have a slight excess of oxygen—one of the very few instances where an oxidizing torch flame is used. Be especially careful in applying heat to brass to avoid burning or oxidizing the zinc content of the brass.

Any good commercial brazing and welding flux will do for this operation, or, in an emergency, borax diluted with boric acid or sodium carbonate may be used. Apply the flux by dipping the hot end of the filler rod in the mixture

or by painting the dissolved flux on the rod. Flux protects the hot metal from the air and other gases by forming a film over it, and also cleans the hot brass of oxides formed during the welding process.

The filler rod for brass should have approximately the same composition as the base metal. As pointed out earlier, a rod with a slightly lower melting point than the base metal gives the best results. Use either a grade A or B rod for this job. Two commercial filler rods which are also good are Tobin bronze and manganese bronze rods.

The joints used in brazing brass are the same as those used in welding.

Be sure to clean the surface with a file or abrasive cloth, and allow for expansion and contraction. Thick pieces of brass must be beveled by filing or by some other mechanical method. Never bevel brass by melting or cutting since this method destroys the zinc in the brass. To reduce the amount of heat required for the actual brazing and lesson the danger of warping, preheat heavy brass parts.

SILVER SOLDERING

Silver soldering is one of the several methods of brazing. The principal use of silver solder is the fabrication of high pressure oxygen lines, and other parts which must withstand vibration and high temperatures. Silver solder is used extensively to join copper and its alloys, nickel, and silver, as well as various combinations of these metals, and thin steel parts. (See table 7-4.)

Silver solder can be obtained in several different grades with silver content ranging from 14.5 to 66 percent, and melting points varying from 1,160° to 1,430°F. The standard forms of silver solder are strips and wires, but it is also made in rod form.

If the job to be performed is one in which the solder may be placed in the joint before applying heat, use the strip form. For joints requiring the solder to be applied after heating, use the wire form.

It is necessary to use flux in all silver soldering operations because of the necessity for having the base metal chemically clean without the slightest film of oxide to prevent the silver solder from coming into intimate contact with the base metal.

A paste flux is used generally in most silver soldering. If a prepared flux is not available, a mixture of 12 parts of borax and 1 part boric acid is satisfactory for high-melting-point silver solder. Prepared flux begins to melt at 800°F, becomes fluid at 1,100°, and remains stable up to 1,600°F. It melts at a slightly lower temperature than the solder.

The joint must be physically clean, which means free of all dirt, grease, oil and paint, and also chemically clean—minus all traces of oxide film. After removing the dirt, grease, and paint, remove any oxide which may be present by grinding or filing the piece until bright metal may be seen. During the soldering operation, the flux continues the process of keeping oxide away from the metal.

Joints to be silver soldered must have smooth edges and must fit tightly together. Only a film of silver solder is usually needed for a sound joint. Strength is not added to the joint and expensive solder is wasted if it is used as filler metal.

In figure 7-23 are presented three recommented types of joints for silver soldering. Flanged, lap, and edge joints, in which the metal may be formed to furnish a seam wider than the base metal thickness, furnish the type of joint which will bear up under all kinds of loads. If a lap joint is used, figure the amount of lap according to the strength needed in the joint. Here is a handy rule of thumb: For strength equal to that of the base metal in the heated zone, the amount of lap should be four to six times the metal thickness for sheet metal and small diameter tubing.

The oxyacetylene flame for silver soldering should be neutral, but may have a slight excess of acetylene. It must be soft, not harsh. During both preheating and application of the solder, hold the tip of the inner cone of the flame about one-half inch from the work. Keep the flame moving so that the metal will not be overheated.

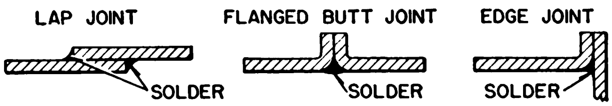
If the piece is large, preheat a considerable area around the joint before applying the solder, especially if the base metal conducts heat rapidly. When soldering two pieces which have different thicknesses, or which conduct heat with unequal speed, gage the preheating so that both parts reach the soldering temperature at the same time.

When both parts of the base metal are at the right temperature (indicated by the flow of flux), begin applying solder to the surface of the under or inner part at the edge of the seam. It is necessary to simultaneously direct the flame

Table 7-4.—Silver solders.

Class	Silver[1] (percent)	Copper[1] (percent)	Zinc[1] (percent)	Other[1] (percent)	Melting point (° F)	Flow point (° F)	Uses
0	20	45	35	--	1,430	1,500	Ordinary brazing purposes where higher physical properties are required than provided by brazing alloys and where service or appearance does not require a high silver content.
1	45	30	25	---	1,250	1,370	Intended for the general range of silver soldering.
2	65	20	15	---	1,280	1,325	High silver content used where high strength, resistance to corrosion, and good appearance is required.
3	15	80	--	[2]5	1,200	1,300	Intended for brazing copper and copper base alloys. Do not use for ferrous alloys.
4	50	15	16	[3]19	1,160	1,175	General purpose intended for brass, copper, ferrous metals and particularly nickel-copper alloys and alloy steels.
5	50	15	15	[3]17	1,195	1,270	Same as class 4, but where design requires addition of a fillet or where close tolerance cannot be maintained and filling is necessary.
				[4]3			Also for hard materials such as cemented carbides for tools.
6	50	15	25	[3]10	1,166	1,190	Same as class 4.
6A	49-51	17-19	20-24	[5]9-11	1,160	1,185	Same as class 4.

[1]Approximate percent. [2]Phosphorus. [3]Cadmium. [4]Nickel. [5]Cadmium.



AM.531
Figure 7-23.—Recommended joints for silver soldering.

over the seam and keep moving it so that the base metal remains at an even temperature.

SOFT SOLDERING

Soft soldering is used chiefly for copper, brass, and coated iron in combination with mechanical seams—that is, seams that are riveted, bolted, or folded. It is also used where a leakproof joint is desired, and sometimes for fitting joints to promote rigidity and prevent corrosion. Soft soldering is generally performed only in very minor repair jobs. This process is also used to seal electrical connections. It forms a strong union with low electrical resistance.

Soft solder yields gradually under a steadily applied load and should not be used unless the loads transmitted are very low. It should never be used as the sole means of attachment of two structural members.

SOLDERING COPPER

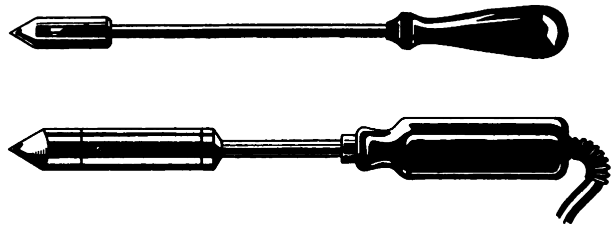
A soldering copper (called a soldering iron if it is electrically heated) is the tool used in soldering. Its purpose is to act as a source of heat for the soldering operation. The bit, or working face, is made from copper, since this metal will readily take on heat and transmit it to the work.

The bit should be relatively blunt. If it is too thin and pointed, it will cool too rapidly. Figure 7-24 shows a correctly shaped bit.

Soldering coppers may be heated by blowtorch or a gas flame. Electric soldering irons have an internal heating element and are especially useful where a constant heat is required, as in soldering electrical connections.

TINNING THE COPPER

To tin the copper, first heat it to a bright red, then clean the point by filing until it is smooth and bright. No dirt or pits should remain on its surface. After the copper has been



AM.532
Figure 7-24.—Soldering copper and soldering iron.

mechanically cleaned, it should be reheated sufficiently to melt solder, and chemically cleaned by rubbing it lightly on a block of sal ammoniac. (If sal ammoniac is not available, powdered resin may be used.) Then apply solder to the point and wipe with a clean, dry or damp cloth.

NOTE: When heating the soldering copper, the heating flame should not be directed on the point as it will form an oxide and prevent good tinning.

The last two operations may be combined by melting a few drops of solder on a block of sal ammoniac (cleaning compound) and then rubbing the soldering copper over the block until the tip is well coated with solder. A properly tinned copper has a thin unbroken film of solder over the entire surface of its point.

If the point of the copper needs reshaping, it should be done by forging. In performing this step, remove all of the oxides and reheat the copper to a bright red. Using a heavy hammer, forge the point to the desired shape on an anvil, then tin in the usual manner.

When using the copper, occasionally dip the point in a solution of one part of sal ammoniac to 30 parts of water. (Keep this solution in an earthenware jar.) If sal ammoniac is not available, powdered resin will serve to tin the point.

The fluxes ordinarily used for soft soldering are solutions or pastes containing zinc chloride. The liquid or paste medium holding the flux material is evaporated by the heat of the soldering operation, leaving a layer of flux on the work. At the soldering temperature, the flux is melted and practically decomposed with the liberation of hydrochloric acid. This acid then dissolves the oxides from the solder and the work. The melted flux also forms a protective

film on the work, preventing further oxidation. Zinc chloride flux is used on iron, copper, brass, and galvanized iron. Muriatic acid is often used in its raw state as a flux for soldering galvanized iron and zinc.

Because zinc chloride fluxes have a corrosive action, it is necessary to employ a noncorrosive flux for work on electrical connections or other places where all traces of flux cannot be removed. Resin, either in powder or paste form, is the most commonly used flux of this type.

Use a noncorrosive commerical flux or a resin flux for electrical connections or where it is impossible to remove all traces of flux from the work. Zinc chloride and other corrosive fluxes must be washed from the work to prevent corrosion.

TYPES OF SOFT SOLDER

Soft solders are chiefly alloys of tin and lead. The percentages of tin and lead vary considerably in various solders, with a corresponding change in their melting points, ranging from 293° to 592°F. "Half-and-half" (50-50) solder is a general-purpose solder and is most frequently used. It contains equal proportions of tin and lead and melts at approximately 360°F.

Soft solders are usually supplied in bar or wire form, although they can also be obtained in pig or granulated form for jobs requiring large quantities of solder. Some wire-shaped solders have a core of flux. The most popular solder of this type has a core of resin and is used chiefly on electrical connections.

The film of solder between the surfaces of a joint must be kept thin to make the strongest joint.

SOLDERING TECHNIQUE

The application of the melted solder requires somewhat more care than is apparent. The parts should be locked together or held mechanically or manually while tacking, as shown in figure 7-25. To tack the seam, touch the hot copper to a bar of solder, then use the drops of solder adhering to the copper to tack the seam at a number of points.

Hold a hot, well-tinned soldering copper so that its point lies flat on the metal at the seam, while the back of the copper extends over the seam proper at a 45-degree angle, and touch a bar of solder to the point. As the solder melts, draw the copper slowly along the seam as in figure 7-26. Add as much solder as necessary without raising the soldering copper from the job. The melted solder should run between the surfaces of the two sheets and cover the full width of the seam. Work along the seam only as fast as the solder will flow into the joint. When the copper cools, reheat it or take another hot copper. Resume work by remelting the solder where the operation stopped, and go on from there.

AM.533

Figure 7-25.—Holding the parts together.

In another type of soldering known as sweating, both surfaces of the pieces to be joined are tinned, then held together and heated with a soldering copper or blowtorch until the solder melts and begins to run out. Remove the copper or torch and keep the parts in close contact by pressure until the solder cools and sets.

POST-SOLDERING TREATMENT

Whether doing hard soldering or soft soldering, the joint must be cleaned when finished. This means the removal of all flux that might cause corrosion or prevent paint from adhering. In some cases, the joint is immersed in a "bright dip" to restore the color.

If the base metal is nonferrous—that is, not made from iron ore—a good solution for removing flux consists of 1 fluid ounce sulfuric acid, 1.5 ounce sodium bichromate, and 1 gallon of water.

AM.534

Figure 7-26.—Soldering a seam.

Boil ferrous metals in a 10 to 15 percent solution of caustic soda for 30 minutes to eliminate the flux. In either case, rinse the metal thoroughly in clean water after treating it.

The job may require that metal which has been discolored by heat, in the soldering process, be restored to its original color. The color of copper and brass particularly seems sensitive to heat. The remedy is a "bright dip" consisting of 68 fluid ounces sulfuric acid, 20 fluid ounces nitric acid, 0.12 fluid ounce of hydrochloric acid, and 40 fluid ounces of water. Following this path, rinse the metal thoroughly in clean, running water.

Scale which is caused by the heating of steel parts may be removed by a light sand blast.

SAFETY PRECAUTIONS

Oxyacetylene welding, brazing, and soldering operations can be very dangerous. Strict adherence to all applicable safety precautions must be observed when performing these operations. Practically all of the welding and cutting operations performed by the ASH are conducted in specifically designated locations. If welding or cutting is to be done in any other location, approval of the job and the precautions to be taken must be obtained from higher authority.

Some of the common hazards encountered and the precautions to be observed when operating welding equipment and around welding shops are as follows:

1. Use only approved apparatus, such as torches, regulators, hose, valves, and accessories that have been examined, tested, and found to be safeguarded in accordance with accepted standards.
2. Only qualified operators are allowed to perform welding, brazing, and soldering operations. NOTE: This does not preclude on-the-job training of nonqualified personnel if supervised by a qualified operator.
3. While the equipment is in use, it must be frequently inspected for evidence of leaks in the hose, couplings, valve stems, or other points of the system. Otherwise, an explosive mixture of gas and air may accumulate with serious results.
4. Positive ventilation of the welding shop/area must be provided and maintained during all welding, cutting, or heating operations to prevent suffocation, fire, and explosion due to gas leaks; heat prostration, and/or illnesses such as metal fume fever or metal poisoning caused by breathing toxic vapors which may be formed under certain conditions.
5. If all fire hazards cannot be removed from the area of welding operations, fire watches must be properly instructed and posted in the vicinity.
6. Suitable fire-extinguishing equipment of approved types must be maintained near all welding and/or cutting operations.
7. Protective clothing must be provided and worn at all times when welding and/or cutting operations are being performed.
8. Not only welding and cutting operators, but also other personnel such as helpers, inspectors, etc., who remain in the vicinity, must use suitable helmets, hand-held shields, or goggles during all welding/cutting operations, in order to protect their eyes from stray flashes, reflected glare, and flying particles.
9. After welding/cutting operations are completed the operator should mark the hot metal or provide some other means of warning others who may inadvertently come in contact with the hot metal.

CHAPTER 8
ELECTRIC ARC WELDING

During World War II, it was necessary to build aircraft, ships, tanks, and various other implements of war in the least time possible. A great deal of credit for the rapid production of these items during the all-out war effort is credited to the use of arc welding. Prior to this time, progress in the field of arc welding was comparatively slow. It took time for industry to recognize its many advantages, and the supply of equipment and experienced operators was limited.

Since World War II, many new developments have been made in arc welding equipment, and now arc welding is one of the most important metal-joining processes. Arc welding offers such advantages as ease of edge preparation; elimination of applying flux to the metal being welded because the rods are flux treated; reduces distortion of the pieces being joined because it confines the heat to a small area; less warping and buckling; less effect on the temper of the metal because of faster welding and more concentrated heat; ability to produce strong, sound and ductible welds; suitability for most metals; and production of satisfactory welds in heavy structural members, as well as light metal sheets.

A basic knowledge of electricity is required in order to understand the operation of electrical welding equipment. In particular, the operator must be thoroughly familiar with the terms used to describe electrical equipment and with the units of measurement used in connection with electricity. This information is contained in the Rate Training Manual, Basic Electricity, NavPers 10086-B, supplementary reading for this Manual.

Electric arc welding is a fusion process based on the principle of generating heat with an electric arc jumping an airgap to complete an electrical circuit. This process develops considerably more heat than an oxyacetylene flame. In some applications it reaches a temperature of approximately 10,000°F.

There are several types of electric arc welding processes. The types most commonly used by the ASH are the metallic arc and inert-gas shielded arc processes. Metallic arc is discussed in this chapter. Inert-gas shielded arc welding is discussed in chapter 9.

In the metallic arc process, the welding circuit consists of a welding machine, two leads, an electrode holder, an electrode, and the work to be welded. The electrode, which is held in the electrode holder, is connected to one lead, and the work to be welded is connected to the other lead. When the electrode is touched to the metal to be welded, the electrical circuit is completed and the current flows. When the electrode is withdrawn from the metal, an airgap is formed between the metal and the electrode. If this gap is of the proper length, the electric current will bridge this gap to form a sustained electric spark, called the electric arc.

The instant the arc is formed, the temperature of the work at the point of welding and the welding electrode increases to approximately 6,500°F. This tremendous heat is concentrated at the point of welding and in the end of the electrode, and simultaneously melts the end of the electrode and a small part of the work to form a small pool of molten metal commonly called the crater.

Under the intense heat developed by the arc, a small part of the work to be welded is brought to the welding point almost simultaneously, and tiny particles of molten metal are formed at the end of the electrode. These tiny particles, or globules, are then forced across the arc and deposited in the molten crater in the work. Because of this fact, it is possible to make overhead welds.

By moving the metal electrode along the joint and to the work, a controlled amount of filler metal can be deposited on the base metal to form a weld.

ARC WELDING EQUIPMENT

A wide variety of welding equipment is available and there are many differences in the makes and models of equipment produced by different manufacturers. However, all types of arc welding equipment are similar in that their basic

function is to produce and handle the high-amperage, low-voltage electrical power required for the welding arc. The following discussion pertains to typical items of arc welding equipment rather than specific items. The appropriate manufacturer's instructions manual should be consulted for information pertaining to specific items of equipment.

WELDING MACHINES

The function of the welding machine is to supply and control the current for arc welding. The means of supplying current of the appropriate voltage is provided by a motor generator or a transformer. Controlling and adjusting the arc length (necessary for the work to be accomplished) is provided by switches and selectors on the welding machine. Provisions for attaching two cables are provided on the welding machine. The ground cable is attached to the ground cable connector on the machine, and the other end is attached to a ground plate or clamp which is attached to the work.

The welding cable is attached to the welding cable connector on the machine, and the other end is attached to the electrode holder. Figure 8-1 shows a typical arc welding circuit.

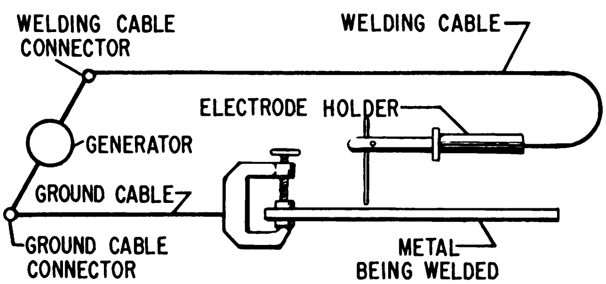


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Figure 8-1.—Typical arc welding circuit.

Arc welding machines are classed as either direct-current (d-c) type welding machines or alternating-current (a-c) type welding machines. Each type has its advantages and disadvantages peculiar to the type of current produced. Advantages such as initial cost, portability, and operating expenses are claimed for each class of welding machines. However, from a welder's standpoint, d-c equipment offers fine current adjustments and choice of polarity. An a-c welder eliminates practically all arc blow (which is troublesome to welders using d-c equipment) especially when making heavy fillet or deep groove welds.

Electric arc welding machines are manufactured in sizes ranging from 100 to 600 amperes for manual welding. Machine sizes are based on their amperage output. For example, a 100-ampere machine will deliver 100 or more amperes (the output is rated conservatively by most manufacturers). Naturally, the range in sizes of arc welding machines is governed by the class and range of work for which it is to be used.

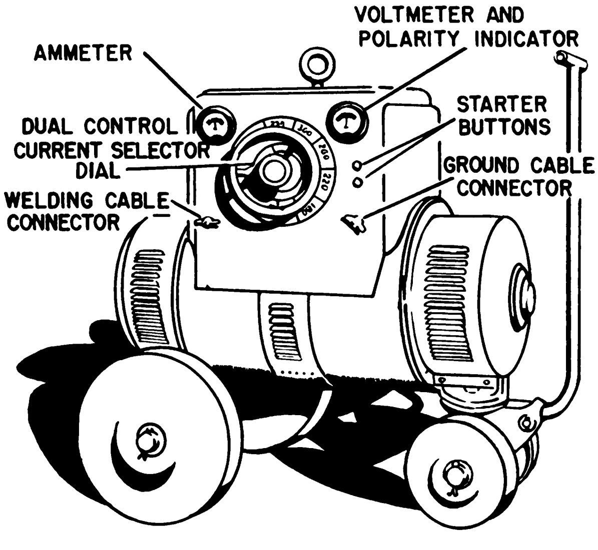
The most widely used is the 200-ampere machine, as it most economically satisfies the needs of the maintenance and repair of aircraft support equipment. A machine of this size will rapidly weld light metals and can also be used for most of the welding of heavier structural members. Each type welding machine is discussed separately in the following paragraphs.

Direct-Current (D-C) Welder

A direct-current welder consists of a direct-current generator driven by a suitable type of motive power. The voltage of such a generator will usually range from 15 to 45 volts across the arc, although any setting is subjected to constant variation due to arc conditions.

A fairly wide range of current output is necessary to accommodate the various kinds of work. The range of current will also vary, depending upon the type unit and work for which it was designed.

In direct-current welders, the generator is of a variable voltage type and so arranged that the voltage automatically adjusts itself to the demands of the arc. However, the open circuit voltage is manually set to the correct range by means of a rheostat mounted on the control panel. Amperage of the welding current is manually adjustable, and is usually set to the proper range by means of a reactance arrangement, or selector switch which taps into the field coils of the generator at different points to increase or decrease its strength. When both voltage and amperage are adjustable by means of individual controls, the machine is referred to as a dual-control type. The dual-control machine is the most popular in use today. Figure 8-2 shows a dual-control direct-current welding machine.



AM.536
Figure 8-2.—Dual-control direct-current welding machine.

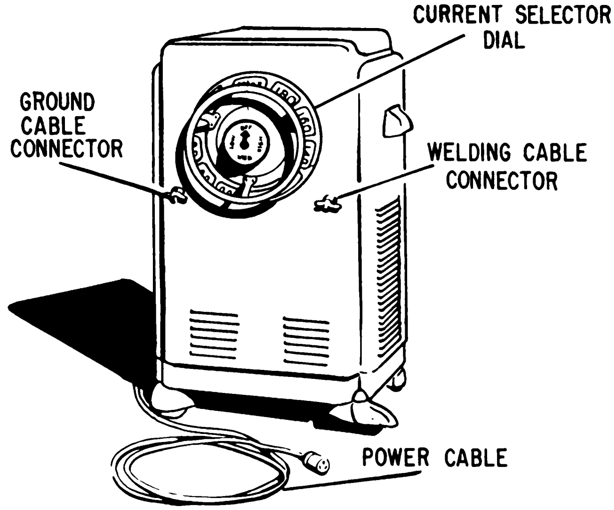
Another system employed to a limited extent makes use of adjustable generator brushes for the control of the current. Machines of this type are provided with one control which proportionately varies both amperage and voltage by the movement of the brush assembly.

When a power supply is available, welding generators are driven by means of an electric motor. The armatures of both generator and motor are usually on a single common shaft. However, some of the older machines are arranged whereby the motor drives the generator through a flexible coupling.

In many instances, arc welding must be performed in places where a power supply is not available. Portable gasoline-engine-driven generators are particularly adaptable in such cases, as they are available in compact units easily transported from place to place. The engine used for this purpose must be fitted with a suitable governor to compensate for the varying loads imposed by the welder.

Alternating-Current (A-C) Welder

The a-c welding machine illustrated in figure 8-3 derives its current from a core transformer. The primary coil is connected directly to the power line, and the secondary coil supplies the welding current. Current control, which varies in different models, is accomplished by either a bridge reactor, movable coil, movable core, or by tapping the secondary coil. All means of current control, except the tapped secondary coil method, offer continuous control.



AM.537
Figure 8-3.—Transformer type (a-c) welding machine.

The a-c welder has rapidly gained in popularity because of advances in machine design and the development of heavy-coated electrodes especially designed for alternating-current welding.

Rectified (D-C) Welders

This type welder is being used extensively for arc welding in the Navy and is one of the most recent developments in the field of arc welding. The d-c rectifier type arc welder combines the advantages of both d-c and a-c welding without their inherent disadvantages.

The d-c rectifier arc welding machine combines a three-phase transformer, a three-phase adjustable reactor, and a three-phase, full wave, high voltage plate type rectifier.

The efficiency of the d-c rectifier arc welder is rated at 66 percent as compared to 54 percent for motor generator welders. In addition to offering economy, it also affords desirable welding characteristics such as extremely rapid

responses to changes in current and voltage conditions. The most outstanding advantages for the machine, however, are claimed on its operation where welding is done at low current densities.

Maintenance of Welders

Proper maintenance of arc welding machines is very important. Because of the dust and grit present in all welding shops, it is necessary to periodically check and clean the machine in order to keep it in the proper working order. The following cleaning instructions apply to most arc welding machines.

NOTE: Prior to attempting any maintenance inside the machine, make sure that the power source is disconnected to avoid any possibility of fatal shock.

Forced draft is used to cool most welding machines, and because of this fact particles of dirt are carried throughout the unit. Under average conditions, the machine should be cleaned with dry, compressed air at least once each month. This may readily be done by removing the dust covers and shields. Should the machine appear greasy at the time of cleaning, it should be dismantled and thoroughly washed with safety solvent (MIL-S-18718). During the regular monthly cleaning, an inspection should be made of the condition of the switch points, brushes, commutator, and bearings.

NOTE: All maintenance performed on the welding machine should be done in accordance with the maintenance instructions manual for the machine concerned.

The machine should be given a thorough greasing at 4- to 6-month intervals. This may follow the cleaning operation and should include all bearings in the unit. Too much grease may be as harmful as not enough, as a surplus may be thrown upon the commutator. Grease on the commutator may result in serious damage or a fire hazard.

To properly grease a bearing of the type used in welding machines, the plug should be removed on the lower side of the bearing boss and the machine started. Grease may then be injected into the fitting until it begins to emerge from the plug hole. Allow the machine to run for several minutes to force out any pressure on the grease, then replace the plug. Only an approved grease should be used.

The brushes and commutators of both the motor and generator are subject to considerable wear. Brushes worn so that spring tension is appreciably reduced must be replaced to maintain proper efficiency of the machine. Although new brushes are formed to fit the commutator, they must often be sanded in to give proper amount of contact. This is done by wrapping a strip of No. 00 sandpaper around the armature and turning it by hand until the brushes have been worked down to a perfect fit. Never use emery cloth.

Brush springs weakened from overheating should also be replaced to assure positive brush contact.

Each time brushes are replaced, the commutator should be checked for cleanliness and wear. If a deposit of graphite from the brushes is found, it may be removed by holding a piece of No. 00 sandpaper against the commutator while the armature is in motion. Ridges or pockets on the surface of the commutator will require the removal of the armature so that it may be "trued up" on a lathe. Only a light cut should be taken, and the mica separators between the bars of the commutators must be undercut from one sixty-fourth to one thirty-second inch after the truing operation. Although a special cutter should be used for this purpose a hacksaw blade ground to the proper thickness will serve in an emergency.

All electrical switch contacts should be sanded clean if pitted. Parts that have been badly burned should be replaced. At least once each year, the windings of the generator and motor should be inspected and, if found dry or cracked, coated with insulating varnishes or resins, carried in stock for this purpose.

WELDING CABLE

The welding current is conducted from the generator to the work by multistrand, well-insulated copper cables, two of which are required to complete the circuit between the welding machine and the work. One cable, extra-flexible, is used between the welding machine and the electrode holder. The other cable is the ground and is connected between the work and the machine. It need not be as flexible as the electrode holder cable, although similar types of cable are sometimes used for both.

Flexible cable is designed especially for welding. It derives its flexibility from its construction, since it is made of thousands of very

fine wires enclosed in a durable paper wrapping which allows the conductor to slip readily within its rubber insulation when the cable is bent. The rubber also contributes to its flexibility. The ability of the cables to withstand wear and abrasion is provided by a tough, braided cotton reinforcing and by the composition and curing of the waterproof rubber covering, which also provides a smooth finish.

The size of the cable is determined by the size of the welding machine and the distance of the work from the machine. As these factors increase, the size of the welding cables must also increase. When the cable is too small in relation to the amperage used, it will become overheated. A cable which is too small will not carry sufficient current to the arc without overheating, but the larger the cable the more difficult it is to handle.

Selection of the size of the cable has a definite and important bearing on welding efficiency. Table 8-1 offers a guide for selection of the correct cable to use on various machines.

It is further recommended that the longest length of 4/0 cable for a 400-ampere welder should not be greater than 150 feet, and for a 600-ampere welder not more than 100 feet. For greater distances the cable sizes should naturally be increased despite the fact that cables of such length and size are difficult to handle. Rather than increase the size of the welding cable, move the machine closer to the work.

ELECTRODE HOLDERS

An electrode holder is essentially a clamping device for holding the electrode. It is provided with a hollow, insulated handle through which the welding cable is passed to connect with the electrode clamping device.

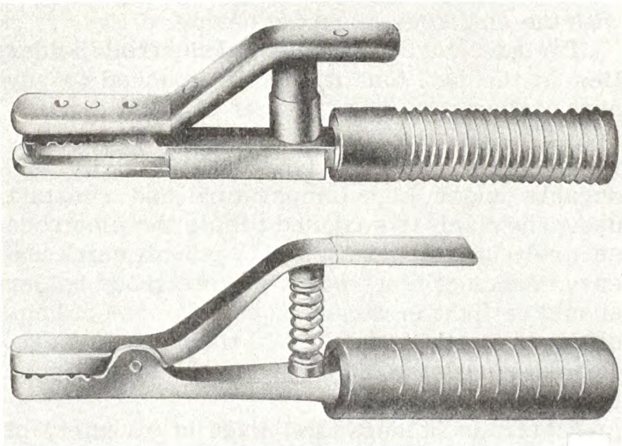
The advantage of an insulated electrode holder lies in the fact that it may be touched to any part of the work without danger of short circuiting. The clamping device is made of an alloy which is a good conductor of electricity and durable under high temperature and constant use. The clamp is designed to hold the electrode securely in any position and to permit quick and easy change of electrodes. An electrode holder should be light in weight to permit ease of handling yet sturdy enough to withstand rough usage. Typical electrode holders are shown in figure 8-4.

Electrode holders are made in a variety of sizes, and each manufacturer has his own system of designation. However, any catalog description of an electrode holder gives the maximum amperage and range of electrodes by diameters which the holder will accommodate. The size used is dependent upon the amperage rating of the welding machine, that is, a larger holder must be used with a 300-amperage welder than with a 100-ampere machine. If the electrode holder is smaller than the type which should be used for a particular machine, the holder will overheat.

CAUTION: The fully insulated type electrode holder should always be used with a-c welding machines since this type holder gives the operator better protection from shock. These holders should be examined to see that there are no exposed screwheads or rivets which might come in contact with the operator and cause a serious shock.

Table 8-1.—Recommended cable sizes.

Machine capacity in amperes	Cable lengths		
	Up to 50 feet (size No.)	50 to 100 feet (size No.)	100 to 250 feet (size No.)
Up to 150	2	2	2
200	2	1	2/0
300	0	2/0	4/0
400	2/0	3/0	4/0
600	2/0	4/0	4/0



AM.538
Figure 8-4.—Electrode holders.

GROUNDING

In many cases where trouble has occurred on a welding job it has been traced to a poor ground connection. Like any other electrical circuit, it takes only one poor connection to destroy the efficiency of the welding circuit.

There are three common methods used to attach the ground cable to the work; bolting, clamping, and tack welding. The bolt method of grounding is generally used when all welding is done on a bench or any permanent fixture with the lug on the end of the ground cable being bolted to the bench. The clamping method of grounding employs a C clamp or a clamp of special design permanently attached to the ground cable which is attached to the welding table or bench. The tack welded method of grounding employs a ground plate which is bolted to the ground cable and tack welded to the work or bench. This method makes a very good ground, however, in some cases its use is not desirable.

In addition to the grounding of the work or welding bench a ground should be provided on the welding machine for grounding the welding machine frame and enclosure preferably located near the power supply connection point. A power supply ground serves to reduce or eliminate shocks from stray currents as well as protect against imposing full supply voltage on the output terminals in the event of a breakdown of the insulation.

PROTECTIVE EQUIPMENT

Exposure of the eyes to the infrared and ultraviolet rays accompanying electric arcs often results in eye-burn or "sand in the eyes," as it is commonly called by arc welders, and may cause extreme pain for 24 to 48 hours. In addition to affecting the eyes, exposure to the arc will produce severe sunburn to portions of exposed skin.

To protect the eyes and face, a head shield should be worn. These shields are constructed of pressed fiber and are solid black in color to reduce reflection. They are light in weight and designed to insure comfort to the welder.

Protective shields are provided with a glass window whose standard size is 2 x 4 1/8 inches. The composition of the glass lens is such that it absorbs the infrared and ultraviolet rays and most of the visible rays from the arc. Table 8-2 lists the recommended welding glass numbers for various welding applications.

The welding lens is protected from metal splatter and breakage by a plain or a chemically treated, clear, nonsplatter glass covering the exposed side of the lens. Green-tinted flash goggles should be worn by the welder to protect his eyes from the flashes of other welders when he removes the shield for purposes such as inspecting his weld. They also protect his eyes when he is grinding, chipping, or cleaning slag. Flash goggles should be worn by all persons working in the vicinity of arc welding operations.

During any arc welding operation, a continuous shower of sparks and hot molten metal is thrown off by the arc. These may cause burns if permitted to contact the skin; therefore, protective clothing must be worn to shield the welder from the spray and sunburn effects of the arc. Leather gloves, preferably of the gauntlet type, protective sleeves of leather, and leather aprons should also be worn at all times. Leather jackets provide excellent protection when welding in the vertical or overhead position. There are many other types of protective clothing, usually made of leather, such as trousers and leggings. Naturally, the type and amount of protective clothing you need will depend upon the position and size of the welding job.

In addition to wearing protective clothing, the welder should keep the collar button on his shirt fastened, and wear ankle-high shoes in preference to oxfords. It is also important that

Table 8-2.—Recommended welding glass numbers.

Welding glass number	Arc welding application (amperes)	Electrode diameter (inches)	Utraviolet (percent trans-mission)	Infrared (percent trans-mission)
6	To 30	1/16	0.2	1.5
8	To 75	1/16, 3/32	.1	1.0
10	75 to 200	1/16, 3/32, 1/8, 5/32	.1	.6
12	200 to 400	3/16, 7/32, 1/4	.05	.5
14	Over 400	5/16, 3/8	.05	.3

trousers without cuffs be worn and that the legs of the trousers be held down over the shoe tops. Bicycle clips are excellent for this purpose. The welder can protect the top of his head with a brimless white hat. Woolen clothing which offers more protection than cotton, should be worn, if possible.

When welding indoors, provisions should be made to remove smoke and fumes by mechanical means. When possible, all inside welding should be done in a special room or booth equipped with a suitable hood, ducts, and fan for exhausting the smoke and fumes and replacing with fresh air. If welding has to be performed in areas other than those mentioned above, as much ventilation as possible should be provided.

CURRENT AND POLARITY

To understand the meaning of polarity, its relationship to the arc welder, and its use, it is first necessary to become familiar with the basic principles of an electric current. A brief discussion of current and polarity is presented in the following paragraphs. For a more complete discussion, reference may be made to the Rate Training Manual, Basic Electricity, NavPers 10086-B.

Electric current is divided into two classifications—direct current (d-c), which is electricity flowing in one direction only, and alternating current (a-c), or current flowing alternately in opposite directions. In the latter, the direction of flow is continually reversing itself.

Electric current consists of a movement of electrons through an electrical circuit, the movement being from the negative terminal of the battery or generator through the electrical circuit to the positive terminal or pole of the source of electromotive force.

In a direct-current circuit, the polarity always remains the same, and the current always flows through the circuit in the same direction; however, in an alternating-current circuit the current continually reverses direction in keeping with the changes in polarity at the terminals of the a-c generator.

The polarity of the voltage drop across any electrical circuit, whether it be an arc, a single resistor, or an entire circuit, is determined by the direction of electron flow (current). The sum of all the voltage drops around the circuit equals the potential developed at the terminals of the generator.

ALTERNATING CURRENT

As previously mentioned, alternating current is current flowing alternately in opposite directions—the direction of flow is continually reversing itself. There are several advantages

in using an a-c welding machine instead of a d-c machine. The advantages and disadvantages of the a-c welding equipment are discussed in the following paragraphs.

Advantages

One fundamental advantage of a-c welding is that it greatly reduces arc blow (distortion of the arc stream from the intended path). Another is the initial cost, which is generally cheaper for the a-c machine, and it is usually less expensive to maintain and operate. In small shops, where the only available power source is a single phase, the a-c welder is readily adaptable to a single or multi-phase power outlet of 110, 220, or 440 volts. The a-c welding transformers are quiet in operation and are highly recommended for welding in restricted places.

Disadvantages

The power available to small shops is often subject to "line surges" to which the transformer welder is extremely sensitive. Alternating-current welding is still handicapped by the fact that suitable electrodes have not been developed for generally satisfactory welding of copper, bronze, aluminum, and other nonferrous metals, as well as for certain hard-surfacing operations. Alternating current is constantly changing from straight to reverse polarity 50 percent of the time, giving no choice of polarity. Welding with a.c. requires that additional safety precautions be observed during welding operations. Operators are more subject to shock and burns than from d-c equipment.

DIRECT CURRENT

Direct current, as previously mentioned, is electricity flowing in one direction only. The d-c welding machine has several advantages over the a-c welding machine. The advantages and disadvantages of the d-c welding equipment are discussed in the following paragraphs.

Advantages

Direct current can be used for welding ferrous and nonferrous metals alike. It can be used where a much greater voltage drop on the electrode or on the plate is essential for satisfactory operation. In the case of many alloys, it is necessary to have a widely different voltage drop on one side of the arc than on the other. Either reverse or straight polarity may be applied to the welding job at hand, depending on the desired characteristics or nature of the weld. The positive side of the arc releases 65 to 75 percent of the heat when using the bare electrode.

Disadvantages

The welding operator must be continually on the lookout for arc blow, which is recognized by the persistency of the arc to flare wildly and tend to wander from the path along which the operator is attempting to conduct it. The initial cost of d-c welding equipment is more than the a-c equipment and is also more costly to maintain and operate. The d-c welding machines also require additional power requirements over those required for a-c equipment.

WELDING CURRENT AND VOLTAGE

The speed at which a welder travels and the quality of the weld will depend largely on the arc force, which is controlled by the amount of current and voltage being used. The limiting speed is usually the highest speed at which the surface appearance remains satisfactory. An increase in current increases the arc force and penetration. To use higher currents, larger size electrodes may be needed. In general, the first indication of excess current will be poor surface appearance of the weld.

As previously mentioned, arc force is controlled by regulating the proper amount of current and voltage, making it necessary for the welding operator to understand their function.

Voltage

Voltage across the arc while welding is determined by arc conditions—including length, temperature, and gaseous content, with length of arc the predominant factor. Generally speaking, as long as the current remains constant, arc voltage increases as the arc is lengthened and decreases as the arc is shortened. Experience has shown that the arc is more stable and easier to maintain without interruptions caused by air currents, magnetic conditions, etc., if the open circuit voltage is at least twice the actual arc voltage. Therefore, for practical purposes, the open circuit voltage should be at least 50 to

60 volts and should be adjusted to higher values when required by certain welding conditions.

Actual voltage across the arc while welding is not shown accurately by the voltmeter on the welding machine because it measures voltage across the terminals of the machine.

Current

In practical arc welding it is impossible to establish a set of current values that can be used satisfactorily under all conditions. Hence, manufacturers of electrodes can only generalize when publishing minimum and maximum current values for a certain size and type of electrode. In actual practice it is not always possible to depend on the meters installed on the welding machine. The operator must learn to determine, by operating the welding equipment, whether he is using the proper current values to produce the desired results with maximum speed and minimum cost.

The procedure to follow in estimating the maximum current setting for different size electrodes follows:

The amperage selection should be equal to the decimal equivalent of the electrode to be used. The voltage selection should be made by using 1/2 the decimal equivalent of the electrode. For example, with a 1/8-inch electrode, use 125 amperes and 62 volts.

Test the current setting by trial and error method on a piece of scrap metal, and adjust the arc amperage and voltage switches until the desired effect is obtained.

POLARITY

As previously mentioned, the polarity in a direct-current circuit always remains the same, and the current always flows through the circuit in the same direction. This is not the case in an alternating-current circuit since the current continually reverses direction in keeping with the changes in polarity at the terminals of the a-c generator. For this reason all the information given on polarity will apply to a direct-current circuit.

There was a time when nearly all welding was performed with direct current and bare metallic electrodes. Under these conditions it was found desirable to connect the positive side of the arc to the work and the negative side to the electrode. This applied a greater portion of the heat to the work, since the positive side of the arc releases 65 to 75 percent of the heat. With the electrode connected to a negative side of the arc, the polarity of the circuit was said to be straight. Figure 8-5 illustrates the hookup for straight and reverse polarity.

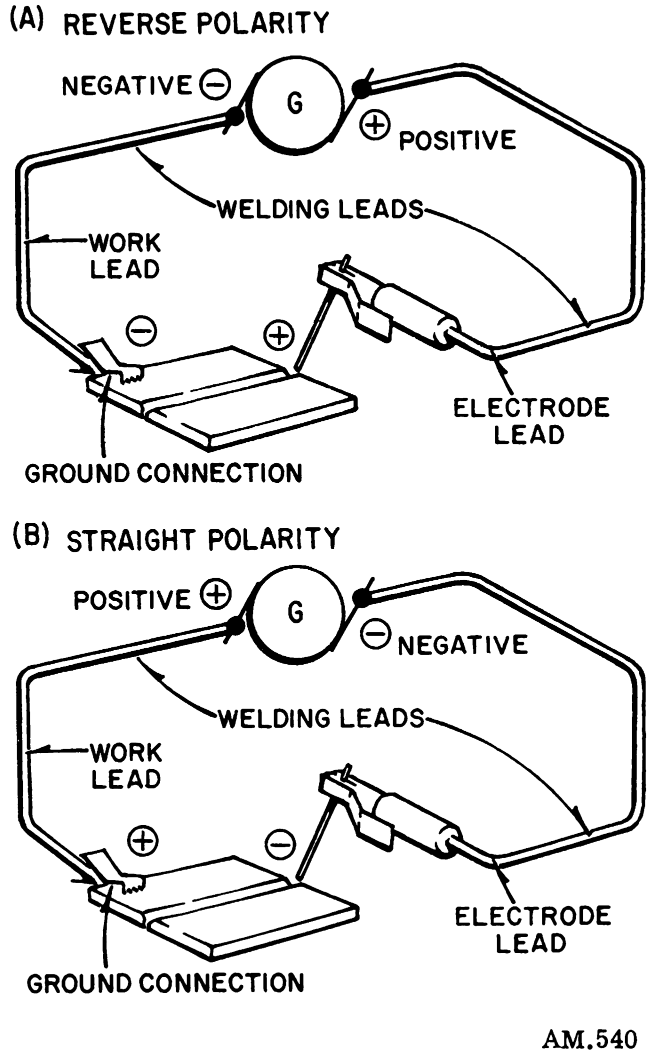


Figure 8-5.—Straight and reverse polarity.

However, different jobs required different welding techniques. For instance, when welding cast iron or nonferrous metals it became important to decrease the amount of heat in the work metal. This was achieved by connecting the work to the negative side and the electrode to the positive. Since the connection had been reversed, the direction of current was reversed, and the welding polarity was said to be reversed, as shown in figure 8-5.

In the early days of arc welding, it was necessary to change the cable connections at the machine, or at the work and electrode, if a change in the polarity was desired. With the advent of shielded metallic arc welding, the change in the polarity to meet the conditions set up by the different coated electrodes became more frequent. Coated electrodes are manufactured for specific jobs, consequently some of them give better results with straight polarity than reversed polarity, while others produce satisfactory results when used with either polarity.

Manufacturers of welding machines soon realized that changing the cable connections to change the polarity for each job with different requirements was a cumbersome method. They therefore designed a polarity switch and mounted it on the control panel, making changing polarity a simple, easy, and quick operation.

The polarity to use with a particular electrode is established by the manufacturer. If doubt exists as to the polarity of the welding current at the electrode holder and ground clamp, simple checks can be made.

One method for checking polarity is with a voltmeter. When the voltmeter connection marked positive is connected to the ground lead and the other connection attached to the electrode holder lead, the needle will register the voltage if the leads are connected for straight polarity. If the voltage indicator needle drops below zero, the leads are connected for reverse polarity. Remember that in straight polarity, the electrode is negative.

If a voltmeter is not available, the polarity may be checked with a carbon electrode. Use two carbon electrodes of the same size and shape. Insert one of the electrodes in the electrode holder, establish an arc on a test plate, and run a bead. Change the welding cables and insert the other carbon electrode in the holder, establish an arc, and run a bead.

The carbon electrode used with straight or negative polarity will maintain its shape, the arc will remain stable, and the electrode will not become excessively hot. The electrode used with reverse or positive polarity will have a blunt, burned off end, the arc will be difficult to hold, and the electrode will become excessively hot.

Perhaps the quickest way to determine polarity is to use the E6010 electrode. This electrode is very sensitive to polarity and is designed to be used with d-c reverse polarity only. It gives so much better results when used correctly that polarity can be determined by merely observing its performance. When used with straight polarity, the E6010 electrode will emit large volumes of smoke and have an excessive "melt-off" rate.

FACTORS AFFECTING WELDS

In electric arc welding there are several important factors which affect the finished weld and must be considered in obtaining good sound welds. Along with melting the electrode and base metal and their subsequent fusing, the arc has the additional and important ability to dig. This digging quality is referred to as arc force.

There is a definite force in the arc stream just as there is in a stream of water flowing from a hose. As water forced through a nozzle will dig dirt, so can the force of the arc stream be used to dig into the base metal. Each of the most common factors affecting welds is discussed in the following paragraphs and, in some instances, they are compared to the flow of water from a hose.

EFFECT OF CURRENT

An increase in current increases the arc force and penetration just as the increase in the volume of water through the size nozzle increases the digging power of the stream of water. To use higher currents, it may be necessary to use a larger size electrode. Generally, the first indication of an excess of current will be poor surface appearance of the weld.

EFFECT OF ARC LENGTH

A further comparison of the arc to a stream of water from a hose can be made to arc length. It is obvious that to dig deep into the dirt the nozzle must be kept near the ground to avoid spreading the stream of water into an ineffective spray.

When a long arc is held, heat is dissipated into the air, the stream of molten metal from the electrode to work is scattered in the form of splatter, and the arc force is spread over a large area resulting in a wide, shallow bead instead of a narrow one with deep penetration.

EFFECT OF TRAVEL AND SPEED ON PENETRATION

The important factor to observe in the utilization of arc force is causing the arc to travel at a sufficient speed to take advantage of the penetrating power of the arc force. This can be further illustrated by the comparison of water flowing from a hose.

The action of digging away dirt with a stream of water is only effective when the stream is directed at the dirt itself, not when directed into the pool of water which soon accumulates. If the stream of water is to keep digging, it must keep moving fast enough to stay ahead of the pool.

The same reasoning can be applied to welding. When the arc is advanced too slowly, a pool of molten metal forms beneath it, and the force of the arc is expended in the molten pool instead of penetrating into the base metal at the root of the joint. This molten metal flows along the joint under the arc and tends to solidify in the root of the weld without fusing to the base metal.

When the arc is advanced at the proper rate of speed, the arc force digs into the base metal and the result is good penetration. However, at a slow rate of arc speed travel, there is usually a small puddle of molten metal under the arc which dissipates the arc force and prevents maximum penetration.

The degree of penetration is proportional to the current used, combined with the effective use of the arc force. An increase in current will increase the arc force and penetration. However, if the speed of travel is too slow, the arc force will be wasted and there will still be less penetration than could be obtained by taking full advantage of the force.

In order to effectively use arc force for penetration, the speed of travel should be fast enough so that the electrode tip will be just ahead of the molten pool at all times, giving the arc force full opportunity to dig deep into the root of the joint. The limiting speed is usually the highest speed at which the surface appearance remains satisfactory.

EFFECT OF ANGULARITY

The angular position of the electrode to the work is also an important factor to be considered in arc welding. The angle of the electrode may determine to some extent the quality of the weld with freedom from undercutting and slag inclusions. The ease with which the filler metal is placed in the weld and the uniformity of fusion and weld contour as affected by the influence of surface tension and gravity on the molten metal may be the determining factor.

The proper angle to use for the different types of electrodes in various welding positions can be obtained from the electrode manufacturer.

EFFECT OF ARC BLOW

Since a magnetic field is set up around any conductor through which electric current is flowing, arc blow is a result of the combined influences of these fields around the arc, the electrode, and the work metal. Arc blow is most likely to occur when welding heavy metal in corners because of the proximity of the sides of the electrode to the metal being welded. Also, arc blow may cause uneven burning of the electrode coating, which in turn, will result in improper fusion.

There are a number of methods by which arc blow may be reduced, minimized, or eliminated. Among these are the following:

1. Reverse the direction of welding.
2. Weld toward a heavy tack or toward a completed weld.
3. Use back stepping on long welds.
4. Change the position of the ground.
5. Wrap the ground cable around the work several times.
6. Use double grounds, one at each end of the weld.
7. Place ground connection as far from the joint as possible.

If arc blow is encountered, try these various methods or a combination of methods until a well-behaved arc is achieved.

NOTE: Check ground connection for security, as a poor ground will sometimes cause fluctuations of the arc quite similar to arc blow.

Arc blow is much less noticeable when welding with alternating current than with direct current. As has been stated previously, this is due to the continuous change in the direction of current flow resulting in very little magnetic action with alternating current.

THERMAL AND MECHANICAL TREATMENTS

In some applications, welded areas require thermal or mechanical treatment. The thermal

and mechanical treatments are necessary to restore the properties of the base metal affected by the heat of the welding arc, to relieve stresses, and to produce the desired structure in the base metal and filler metal.

The use of thermal and mechanical treatment is not required on most welds since the condition of the base metal and filler metal meets the job requirements. However, if any occasion should arise where it is necessary to use thermal or mechanical treatments to bring the welded area up to specifications, consult the Welding Handbook, Fourth Edition, published by the American Welding Society, for specific information on these treatments.

WELDING ELECTRODES

Electrodes are manufactured in a variety of metals and are available for use with any alloy that is classified as weldable by the electric arc welding process. This includes various types of stainless steel, high tensile steels, and manganese steels. Electrodes are also available for welding nonferrous metals and alloys such as aluminum, copper, nickel, and certain types of bronze and brass, some of which were originally considered unweldable.

Electrodes are also manufactured for use with either straight polarity, reverse polarity, or both. They are also designed to be used in the different welding positions; for example, an E6030 electrode is designed for flat welding and is not suitable for vertical or overhead welding positions.

Electrodes are available in a variety of diameters ranging from 1/16 to 3/8 inch and in lengths generally shorter than the rods used in gas welding. Standard lengths are 9, 12, 14, and 18 inches. They are also available in rolls for use in machine welding.

TYPES

Electrodes are typed according to their coating. There are three main types—bare, medium, or light coated, and heavy coated or shielded electrodes. Each type is discussed separately in the following paragraphs.

Bare Electrodes

Bare electrodes are made of wire containing a definite composition. The surface of the bare electrode has not been treated by the addition of special coatings, other than those materials retained from wire drawing operations. These coatings are required in wire drawings and their slight stabilizing action on the arc is only incidental. Finished annealed wire is also classified under this type. The bare electrode was the first step forward from the old carbon arc process to the modern methods.

The weld performed with this electrode has a low strength weld deposit as compared to other methods. However, it is still used for training purposes and to a limited extent for welding where it is desired to eliminate the flux deposit and the need for removing the flux after welding. Figure 8-6 illustrates the transfer of metal across the arc using a bare electrode.

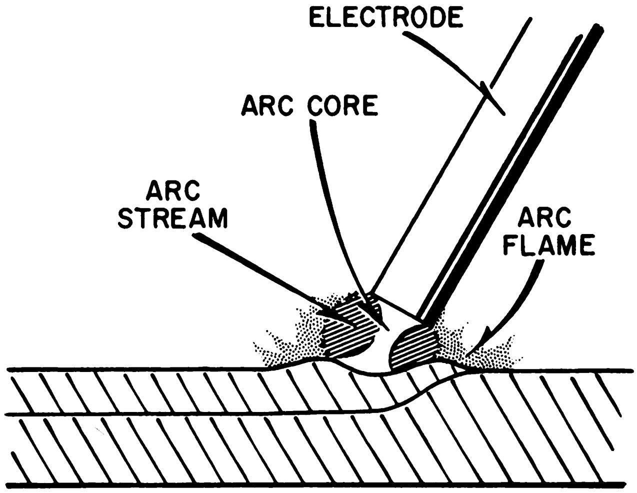


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Figure 8-6.—Molten metal transfer when welding with bare electrode.

Light or Medium Coated Electrodes

The surfaces of light or medium coated electrodes have a thin coating of flux applied by either a washing, dipping, brushing, tumbling, spraying, or drawing process. This improves the stability and characteristics of the arc stream. These coatings are chiefly iron oxides and titanium dioxide.

In general, these light coatings accomplish the following functions: They dissolve or reduce impurities such as oxides, sulphur, and phosphorous, thereby eliminating or reducing them

in the weld deposit. They reduce the adhesive force between the molten metal and the end of the electrode, or change the surface tension of the molten metal so that globules of molten metal leaving the end of the electrode are smaller and more numerous, making the flow of molten metal more uniform and continuous. They also increase the arc stability. Figure 8-7 illustrates the arc characteristics when using a light or medium coated electrode.

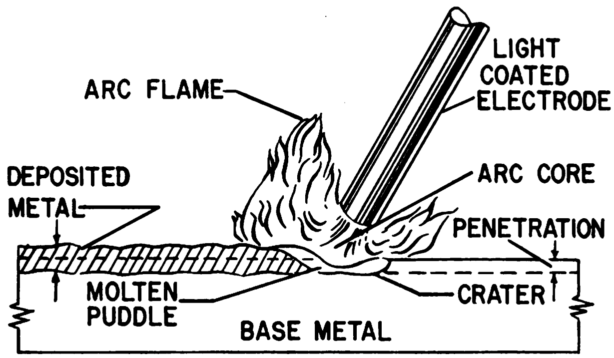

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Figure 8-7.—Arc characteristics when using a light or medium coated electrode.

Some of these coatings may produce a slag, but it is quite thin and does not act in the same manner as the shielded arc type electrode slag.

Heavy Coated (Shielded Arc) Electrodes

The surface of heavy coated electrodes is comparatively thick. These coatings have been designed to improve the physical properties of the weld deposit by providing an inert atmosphere around the arc and weld. They also control arc stability and, as a result, increase the speed and ease of welding in the vertical and overhead positions. These electrodes are manufactured by the extrusion, wrapping, or heavy dipping processes, or combinations of these methods.

The coatings used on these electrodes consist of two basic materials—mineral coatings and cellulose coatings; however, a combination of the two materials may also be used. The mineral coatings consist of metallic oxides such as clay, feldspar, asbestos, and titanium. The cellulose coatings consist of materials such as wood pulp, sawdust, and cotton.

These heavy coating materials on the electrodes accomplish the following: They produce a reducing or nonoxidizing atmosphere which acts as a shielding medium around the arc and weld deposit, excluding the oxygen and nitrogen of the air. They stabilize the arc and improve the flow of metal from the end of the electrode to the puddle on the work. The coating controls fluidity of the puddle and shape of the bead by providing those ingredients (oxides and silicates) which, when melted, form a slag over the molten metal. This slag, being quite slow to solidify, holds the heat and allows the metal to solidify and cool slowly. This slow solidification allows dissolved gases to escape and permits solid impurities to float to the surface. The slow cooling also has an annealing effect on the weld deposit. Heavy coatings also control the physical properties of the weld deposit and the composition of the deposit by the addition of various metals and alloys to be deposited during the welding process. Figure 8-8 illustrates the arc characteristics when using a heavy coated (shielded arc) electrode.

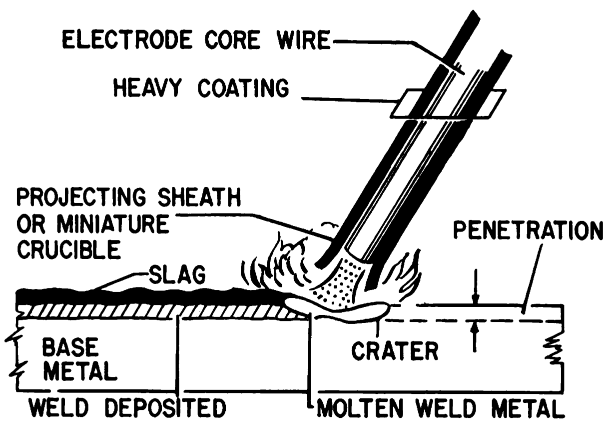

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Figure 8-8.—Arc characteristics when using a heavy coated (shielded arc) electrode.

Coated electrodes should be kept stored in their original containers or in a dry area to prevent the coating from absorbing moisture from the air, especially when the relative humidity is very high. This is especially true of

Table 8-3.—Electrode classification.

AWS-ASTM classification	Type of coating or covering	Capable of producing satisfactory welds in positions shown	Type of current
E60 Series.—Minimum Tensile Strength of Deposited Metal in As-Welded Condition 60,000 psi (or higher).			
E6010	High cellulose sodium	F, V, OH, H	For use with d-c, reverse polarity (electrode positive) only.
E6011	High cellulose potassium	F, V, OH, H	For use with a-c or d-c reverse polarity (electrode positive).
E6012	High titania sodium	F, V, OH, H	For use with d-c, straight polarity (electrode negative), or a-c.
E6013	High titania potassium	F, V, OH, H	For use with a-c or d-c, straight polarity (electrode negative).
E6014	Iron powder, titania	F, V, OH, H	For use with d-c, either polarity or a-c.
E6015	Low hydrogen sodium	F, V, OH, H	For use with d-c, reverse polarity (electrode positive) only.
E6016	Low hydrogen potassium	F, V, OH, H	For use with a-c or d-c reverse polarity (electrode positive).
E6018	Iron powder, low hydrogen.	F, V, OH, H	For use with a-c or d-c, reverse polarity
E6020	High iron oxide	H-Fillets, F	For use with d-c, straight polarity (electrode negative), or a-c for horizontal fillet welds; and d-c, either polarity, or a-c, for flat-position welding.
E6024	Iron powder, titania	H-Fillets, F	For use with d-c, either polarity, or a-c.

Table 8-3.—Electrode classification—Continued.

AWS-ASTM classification	Type of coating or covering	Capable of producing satisfactory welds in positions shown	Type of current
E60 Series.—Minimum Tensile Strength of Deposited Metal in As-Welded Condition 60,000 psi (or higher)—Continued.			
E6027	Iron powder, iron oxide	H-Fillets, F	For use with d-c, straight polarity (electrode negative), or a-c for horizontal fillet welds; and d-c, either polarity, or a-c, for flat-position welding.
E6028	Iron powder, low hydrogen	H-Fillets, F	For use with a-c or d-c, reverse polarity.
E6030	High iron oxide	F	For use with d-c, either polarity, or a-c.

The abbreviations F, H, V, OH, and H-Fillets indicate welding positions as follows:

F = Flat
H = Horizontal
H-Fillets = Horizontal Fillets

V = Vertical
OH = Overhead
} For electrodes 3/16 in. and under, except 5/32 in. and under for classifications EXX14, EXX15, EXX16 and EXX18.

the iron powder and low hydrogen coatings, as an increase in their moisture content will produce unsatisfactory welds. In some cases it is necessary to dry out the electrode coatings by baking the electrodes in a furnace or oven before using them to weld.

CLASSIFICATION

Electrode classification tables are prepared and published jointly by the American Welding Society (AWS) and the American Society for Testing Materials (ASTM). These tables are available in booklet form from either of the above organizations. In order to illustrate these tables, the E60 series classifications are shown in table 8-3.

As shown in the table, the electrode classifications contain the electrode classification number, type of coating, welding positions, and the recommended current and polarity.

To understand the significance of classification numbers, consider the E6010 classification shown in table 8-3. The E represents the word electrode. The first two numbers—60—refer to the minimum tensile strength in the stress-relieved condition, or 60,000 psi. The third number explains the possible welding positions, such as "1" for all welding positions (flat, vertical, overhead, and horizontal); or "2," which designates a greater restriction in choice by being usable only in the horizontal fillet and flat positions; whereas a "3" in the third number indicates that these electrodes may be applied in the flat position only. The fourth number in the classification indicates subgroups, and may be either "0," "1," "2," or "3" under the present system. Table 8-4 defines the meaning of the numbers found in the subgroup.

Some electrodes are classified in five-digit numbers instead of four. In this case the first three digits apply to the minimum tensile strength as previously explained for the four-digit classification. Figures 8-9 and 8-10 illustrate the decoding of the four- and five-digit electrode classification numbers.

In addition to the electrode classification numbers, iron and steel electrodes may be identified by a standard color code set up by the National Electrical Manufacturers Association (NEMA).

This method of electrode identification employs a two-color system consisting of a primary color located on the end of the electrode and a secondary color located near the top end of the electrode. Figure 8-11 shows the location of the primary and secondary color markings on end grip and center grip electrodes. Part of the electrode color identification table produced by NEMA is reproduced in table 8-5.

SELECTION

The first determining factor in the selection of the proper welding electrodes is the type of welding machine being used. If a d-c welding machine is being used, it is important to consider the polarity. In some applications it is faster and more economical to use a straight polarity electrode, and there are other applications where reverse polarity electrodes are more satisfactory.

In shops equipped with a-c welding machines, only electrodes specified for use with a-c welders should be used. In addition to the type of welding equipment being used, there are several other factors which influence the selection of the proper electrode. They are listed in the following paragraphs.

Type or Kind of Metal to be Welded

This includes different metals such as mild, steel, high carbon steel, high tensile steel, stainless steel, cast iron, and any other metal that can be successfully arc welded.

Mechanical and Physical Properties Required of Fabricated Joint

This includes tensile strength, ductility, and hardness of resistance to wear.

Welding Position

The four welding positions are flat, horizontal, vertical, and overhead. When welding is done in a flat position the weld metal can be quite fluid. This results in the best appearing welds and maximum welding speed. Horizontal position welding requires electrodes possessing a very forceful penetration so weld metal will reach the root of the joint. Vertical and overhead joints require electrodes having the same characteristics as those used for horizontal welding. However, because there is an increased tendency of the molten metal to run out, electrodes for this type of welding must also produce a fast-cooling slag.

Table 8-4.—Electrode classification.

4th digit	Power supply	Quality	Arc type	Penetration
"0"	*	High	Digging	Deep
"1"	A-C or D-C	High	Digging	Deep
"2"	A-C or D-C	Moderate	Medium	Moderate
"3"	A-C or D-C	Moderate	Soft	Light

* D-C Reverse polarity.

E 60 1 0 4th digit—Power supply, quality, type of arc, and amount of penetration.

3rd digit—Recommended position.

1st two digits—Tensile strength in thousands psi.

E - Electrode

AS.685

Figure 8-9.—Decoding a four-digit electrode classification number.

E 100 1 0 Same as for a four-digit number.

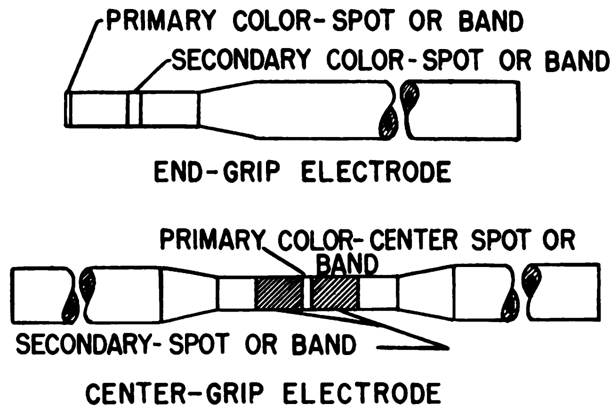
Same as for a four-digit number.

1st three digits—Tensile strength in thousands psi.

Electrode.

AS.686

Figure 8-10.—Decoding a five-digit electrode classification number.



AM.544

Figure 8-11.—Location of electrode color markings.

Condition of the Metal to be Welded

It is naturally desirable to have all joints as clean and free from grit, rust, and oil as possible. However, when this is not practicable, electrodes possessing characteristics of cleaning action and penetration should be selected. When the welding surface is coated with a plating metal, a strong arc is also necessary. However, a clean joint is always the most desirable.

Joint Preparation and Joint Fit Up

The joint influences welding speed and economy, making it desirable that parts fit well. The best electrode for welding a properly prepared joint is the one which affords the greatest speed after meeting the load and stress requirements of the joint. There are many cases, however, where "poor fit up" joints cannot be avoided. Then, an electrode that has excellent "poor fit up" qualities should be used. A "poor fit up" joint should not be confused with a properly spaced Vee joint having a backup strip.

WELDING PROCEDURES AND TECHNIQUES

The quality of a weld depends not only upon the welding process, but also upon the preparation of the metal and the equipment. These preparations, welding techniques, and specification for various arc welds are described in the following paragraphs.

Table 8-5.—Color markings for electrode identification.

Spot or secondary color	Primary Colors				
	Mild steel and low alloys (See Note I)			Special purpose	Hard surfacing (See Note II)
	All positions	Horizontal fillets & flat	Flat position only		
	No Color	Blue	White	Orange	Brown
No color	E6010	E6020	E6030	Mild steel for cast iron	0.40-0.70% carbon
Blue	E6011				0.90-1.10% carbon
White	E6012			Cast iron for cast iron	Brinnell 200 min
Brown	E6013			0.5-1.0% Ni	Brinnell 300 min
Green	E7010	E7020	E7030	2.0-3.0% Ni	Brinnell 400 min
Red	E7011			12.0-14.0%Nm	Brinnell 500 min
Yellow	E8010 E8011	E8020	E8030	Ni . Mn	Brinnell 600 min
Black	E9010 E9011	E9020	E9030	Ni . Cr . Mo	Brinnell 700 min
Orange	E10010 E10011	E10020	E10030	Ni . Cr . Cu	
Violet					
Gray					

Note I: Electrodes listed with prefix letter are AWS designated grades.
Note II: Hardness shall be determined as follows:
(a) Use a base plate of mild steel 5" square x 1" thick.
(b) Use 3/16" electrode.

CHECKING EQUIPMENT

The first step in preparing to arc weld is to make certain that all the necessary equipment is available and that the welding machine is properly connected and in good working order. Make certain that all connections are correct and tight. Particular attention should be paid to the ground connection, as a poor connection will result in a fluctuating arc, difficult to control. To make a good contact, the clamp should be cleaned and the point of contact thoroughly brushed.

The electrode is clamped to its holder at right angles to the jaws. Shielded electrodes have an end of the electrode free of coating to provide good electrical contact. Handle the electrode holder with care to prevent accidental contact with the bench or work, as such contact may weld it fast.

Before commencing to weld, the following list of items should be checked off:

1. Is the machine in good working order?
2. Have all connections been properly made? Will the ground connection make good contact?
3. Has the proper type and size electrode been selected for the job?
4. Is the electrode properly secured in the holder?
5. Has sufficient protective clothing been provided, and is it in good condition?
6. Is the work metal clean?
7. Does the polarity of the machine coincide with that of the electrode?
8. Is the machine adjusted to provide the necessary current for striking the arc?

SETTING UP THE WELDING MACHINE

The machine most likely to be found in the welding shop will probably be a d-c dual control type, rated at 200 amperes, and therefore this type of machine will be used in the following discussion. As previously stated, these units have two controls—one for open-circuit voltage, the other for amperage.

Manufacturers of welding machines use different dial markings, and it is advisable to refer to the manufacturer's operating manual for specific information concerning a particular machine. This manual will furnish the necessary information for adjustment to proper amperage and voltage values necessary for particular jobs. The general procedure, regardless of the machine dial markings, will follow the pattern described below.

After checking the polarity of the machine to make certain that it coincides with the electrode used, set the machine at the highest open circuit voltage within the limits of the job. This makes it easier to maintain the arc. Then set the amperes at the lowest recommended ampere setting, according to the diameter of the electrode. This is the preliminary setting.

Begin the weld at this setting and increase the amperes (heat) and lower the voltage until the arc and the resulting weld are satisfactory. Most welders run an experimental weld until the machine is adjusted to their individual liking. Good welders weld as much by ear as they do by eye, and they judge a good arc by the satisfying frying sound which it makes.

There are a number of variable factors affecting the machine setting. These include size and type of electrode, thickness of metal to be welded, type of joint, and skill and technique of the welder. With these variables to be considered, it is apparent that any set of current values could be merely generalization. Current values as published by different manufacturers vary considerably for the same classification and size of electrode.

Table 8-6, compiled by the American Welding Society, is included for information, but the current values in this chart are merely suggestive. A setting on the welding machine within these ranges should be used only as a preliminary setting since the table is intended to cover all welding positions.

The proper welding current for a given set of conditions can be determined from the degree of electrode heat. If the electrode becomes excessively hot, it indicates that the current is too high. Welds of good quality cannot be made if the electrode overheats, and in such instances the current must be reduced or the size of the electrode increased. With proper current and electrode, a smooth, uniform bead should result.

PREPARATION OF WORK

The strength of any weld may be appreciably affected by lack of proper preparation of the work. Better strength is always obtainable when the work metal is clean and free of foreign matter. It is also highly important that the edges be prepared in a manner that will permit complete fusion without an excessive amount of heat. This is also necessary in order to minimize the amount of heat radiating from the weld to the surrounding base metal.

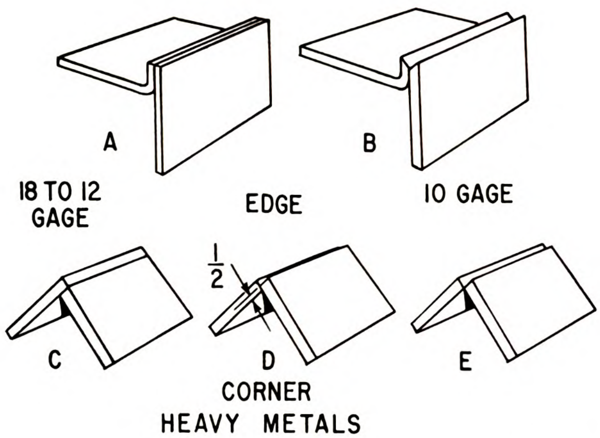
The same five types of joints are used to weld various forms of metal by either the oxyacetylene or the electric arc method. These are the butt joint, tee joint, lap joint, corner joint, and the edge joint. The kind of joint, thickness of metal, direction of welding, facilities for preparing the metal, and the load to which the weld is to be subjected govern the preparation of the joint. Figure 8-12 illustrates the preparation of edge and corner joints for arc welding.

Welds are commonly identified by the kind of joint involved, being referred to as butt welds, lap welds, edge welds, tee welds and corner welds. Obviously, a so-called butt weld may be of either the bead or groove type, according to the preparation of the joint.

Table 8-6.—Typical current ranges in amperes for electrodes.

Electrode diameter, inch	E6010 and E6011	E6012	E6013	E6020 and E6030	E6027	E6014 and E7014	E6015, E6016, E7015, and E7016	E6018 and E7018	E6024, E6028, E7024, and E7028
1/16	. . .	20 to 40	20 to 40	. . .	. . .	. . .	. . .	. . .	. . .
5/64	. . .	25 to 60	25 to 60	. . .	. . .	. . .	. . .	. . .	. . .
3/32	40 to 80	35 to 85	45 to 90	. . .	. . .	80 to 125	65 to 110	70 to 100	100 to 145[a]
1/8	75 to 125	80 to 140	80 to 130	100 to 150	125 to 185	110 to 160	100 to 150	115 to 165	140 to 190
5/32	110 to 170	110 to 190	105 to 180	130 to 190	160 to 240	150 to 210	140 to 200	150 to 220	180 to 250
3/16	140 to 215	140 to 240	150 to 230	175 to 250	210 to 300	200 to 275	180 to 255	200 to 275	230 to 305
7/32	170 to 250	200 to 320	210 to 300	225 to 310	250 to 350	260 to 340	240 to 320	260 to 340	275 to 365
1/4	210 to 320	250 to 400	250 to 350	275 to 375	300 to 420	330 to 415	300 to 390	315 to 400	335 to 430
5/16	275 to 425	300 to 500	320 to 430	340 to 450	. . .	390 to 500	375 to 475	375 to 470	. . .

[a]These values do not apply to E6028 and E7028 classifications.



AM.545
Figure 8-12.—Preparation of edge and corner joints for arc welding. (A) For metals 18 to 12 gage; (B) for 10-gage metals; (C), (D), (E), for heavier sheet.

WELDING PROCESS

There is quite an art to arc welding and an individual can become a proficient welder only by practical experience. However, he must follow certain established procedures and develop the proper techniques to attain this skill. The basic procedures and some of the basic techniques are discussed in the following paragraphs.

Striking the Arc

The welding arc is established by touching the plate with the electrode and immediately withdrawing it a short distance. At the instant the electrode touches the plate, a rush of current flows through the point of contact. As the electrode is withdrawn, an electric arc is formed, melting a spot on the base metal and the end of the electrode.

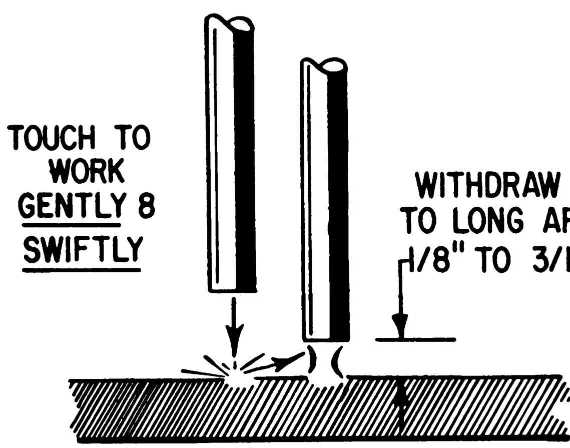
The main difficulty confronting a beginner in striking the arc is freezing—that is, sticking or welding the electrode to the work. If the electrode is not withdrawn promptly upon contact with the plate, the high amperage will flow through the electrode and practically short circuit the welding machine. The heavy current melts the electrode, which sticks to the plate before it can be withdrawn.

Relaxation while welding is important. Gripping the electrode holder too tightly causes the muscles used to control the electrode to be under tension, and the welder tires easily and loses the control essential to a good weld. To relieve some of the electrode holder's weight, the cable may be draped over the welder's shoulder or coiled in his lap. The holder is usually gripped in one hand, which may be supported by the other. You should use the position which is most natural and which suits the position of the job being performed.

The hand gripping the electrode holder, as illustrated in figure 8-13, is supported by the other hand for added steadiness. Elbows are kept close to the body and the cable is draped over the shoulder—an excellent position for the beginner. When you have learned to control the electrode with both hands and have gained confidence, you should develop the ability to control the electrode with one hand.

AM.546
Figure 8-13.—Proper technique for flat arc welding.

There are two essentially similar methods of striking the arc. The first is a vertical up-and-down tapping motion, illustrated in figure 8-14. While this method is commonly used by experienced operators, it often presents difficulties to the beginner. The second method of striking the arc, illustrated in figure 8-15, consists of a side-scratching motion of the end of the electrode in which the electrode tip barely grazes the surface of the plate, making contact and establishing the arc.

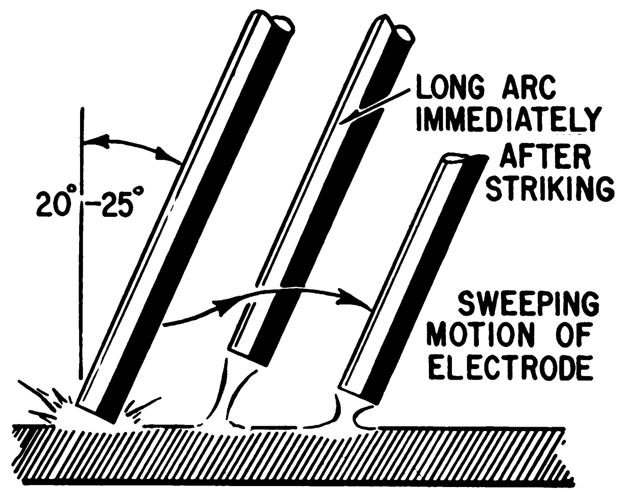


AM.547
Figure 8-14.—Touch method of starting the arc.

Regardless of the method used, the electrode must be withdrawn quickly upon contact with the plate so as to provide the gap necessary to maintain the arc.

Try the first, or touch, method for striking the arc, as shown in figure 8-14. Hold the electrode in a vertical position, lowering it until it is an inch or so above the point where the arc is to be struck. Hold it in this position without touching the electrode to the plate, and lower the face shield into position. Touch the electrode very gently and swiftly to the work, using a downward motion of the wrist, and immediately withdraw it to form a long arc (1/8 to 3/16 inch). Hold the arc for a few seconds, then break it.

To strike the arc by the scratch method, move the electrode downward until it is just above the plate and at an angle of 20 to 25 degrees, as shown in figure 8-15. Hold it there without touching the plate, then drop the shield



AM.548
Figure 8-15.—Scratch method of starting the arc.

to protect the eyes. Strike the arc gently with a swiftly sweeping motion, scratching the electrode on the work with a wrist motion. Immediately withdraw the electrode to form a long arc. Hold the arc for several seconds, then break it.

The purpose of holding an excessively long arc immediately after striking is to prevent the large drops of metal, passing across the arc at this time, from shorting out the arc and thus causing freezing. This also helps to more smoothly fuse one bead with the previously deposited bead.

Practice striking the arc until proficiency and skill are attained. After the arc can be struck with ease, hold it long enough to run a bead of about one-half inch. Remember that a good arc, with correct current value and length, is characterized by an unmistakable frying sound.

Length of Arc

The distance through the center of the arc from the electrode end to the point where the arc contacts the metal is referred to as arc length. With coated electrodes, the length is measured from the metallic core rather than the coating because the metallic core may burn away more rapidly than the coating.

Bare electrodes generally use an arc length equal to their diameter. Too long an arc results in poor fusion, excessive spatter, and a contaminated weld. Too short an arc may cause a very porous weld and may include particles of slag. In practice, the arc length will be determined by the kind of electrode, its diameter, position of welding, and amount of current used.

Maintaining the Arc

The arc is maintained by a uniform continuous movement of the electrode toward the work to progressively compensate for that portion which has been melted and deposited in the weld. At the same time, the electrode is also progressively advanced in the direction of the weld.

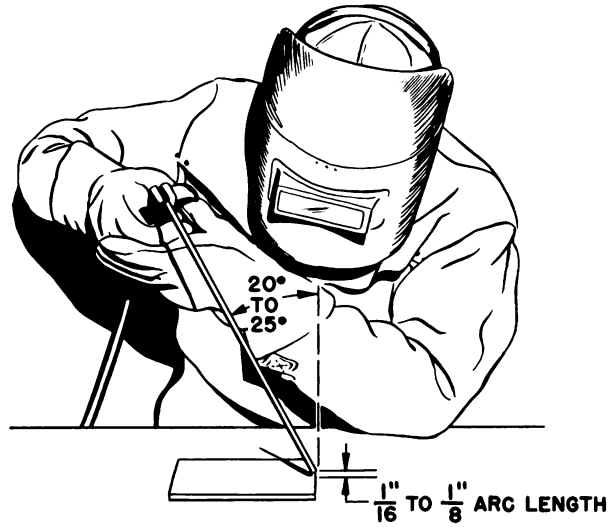
Running a Bead

A weld is a single bead or a combination of beads, and it is thus important for the arc welder to understand the difference between good and bad beads.

A bead is the metal deposited by one pass of the arc welding electrode. When a weld is made up of more than one bead, it is called a multiple pass weld.

To form a uniform bead, the electrode must be moved along the plate at a constant speed, in addition to the downward feed of the electrode. The rate of advance, if too slow, will form a wide bead resulting in overlapping, with no fusion at the edges. If the rate of advance is too fast, the bead will be too narrow and have little or no fusion at the plate. When proper advance is made, no overlapping occurs, and good fusion is assured.

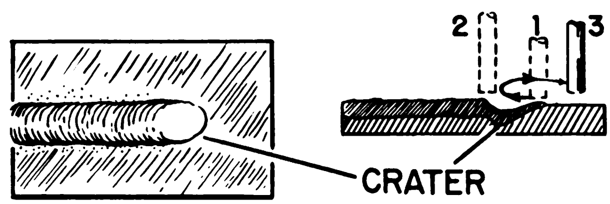
In advancing the electrode, it should be held at an angle of about 20-25 degrees in the direction of travel, as illustrated in figure 8-16.



AM.549
Figure 8-16.—Angle of electrode.

Restarting the Arc

If the arc is broken during the welding of a bead, a crater will be formed at the point where the arc ends. The arc may be broken by feeding the electrode too slowly or too fast, or when the electrode should be replaced. The arc should not be restarted in the crater of the interrupted bead, but just ahead of the crater on the work metal. Then, the electrode should be returned to the back edge of the crater. Figure 8-17 illustrates the procedure for restarting the arc.



AM.550
Figure 8-17.—Restarting the arc.

From this point, the weld may be continued by welding right through the crater and down the line of weld, as originally planned.

Every particle of slag must be removed from the vicinity of the crater before restarting the arc. This prevents the slag from becoming trapped in the weld.

After learning to weld straight line beads, it is good practice to weld in one direction to the end of the plate, move slowly to the side, then reverse the direction of travel.

Spend sufficient time on this exercise to become proficient in holding the proper length of arc and moving the electrode along the plate at the correct speed, so as to secure smooth, even beads.

Study the accompanying chart in table 8-7. hen continue practicing until you are able to ıake a weld by the correct procedure indicated.

'eaving Technique

When depositing weld metal, it is often de-irable to make the width of the deposit wider ıan is obtained by depositing a single bead. 'his is accomplished by a technique known as 'eaving, or moving the electrode from side to ide during the forward motion.

There are a number of different weaving ıotions used in welding, but in all cases it is mportant that the motion used be uniform. 'ypical weaving motions are illustrated in fig-re 8-18.

If the weave used is not uniform, or close nough, there is danger of poor fusion at the dges and of slag being trapped in the center.

3reaking the Arc

There are two procedures used in breaking he arc. In one, the arc is shortened and the lectrode moved quickly sideways out of the rater. This method is used in manual welding vhen electrodes are changed and the weld is to e continued from the crater.

The other method requires that the electrode e held stationary long enough to fill the crater ınd then gradually withdrawn. It is used in nanual welding when it is desired to minimize r to eliminate the crater.

⁄ULTIPLE PASS WELDING

Groove and fillet welds in heavy metals often equire the deposit of a number of beads in rder to complete a weld. It is important that he beads be deposited in a predetermined se-uence in order to produce the soundest welds vith the best proportions. The number of beads s, of course, determined by the thickness of the netal being welded.

The sequence of the bead deposits is deter-nined by the kind of joint and the position of the netal. All slag must be removed from each ead before another bead is deposited. This is nost important, and will be discussed more ully in the section on joints and techniques of osition welding. (See fig. 8-19.)

SPECIFICATIONS FOR ARC WELDS

The specifications which follow are for arc welding required in general maintenance and repair work, such as the manufacture of work stands, storage racks, etc.

Bead Weld Specifications

A bead deposited on a metal surface to build it up to a greater height or thickness should be approximately 1 1/2 times as wide as the diameter of the electrode being used. Generally, an inch of bead length should be deposited for every inch of electrode used. Beads adjoining other beads on the base metal should be fused to one-fifth of their width on either or both sides, depending on the situation.

Groove Weld Specifications

The depth of the throat designates the size of a groove weld, whether it be in a butt joint or an outside corner joint. If the plates being welded are of different thicknesses, the thickness of the lighter plate designates the size of the weld. The amount of metal extending above the surface of the base metal is called reinforcement, and it may range from one-thirty-second to one-eighth inch. If the amount of reinforcement is greater than one-eighth inch, the joint will probably concentrate stresses at the edge of the groove, rather than increasing the strength of the joint. On the other hand, insufficient reinforcement fails to develop sufficient strength. The width of a butt weld should be approximately one-eighth to one-fourth inch more than the face of the groove.

Fillet Weld Specifications

A fillet weld is measured by the length of its shortest leg if the weld has a flat face. If the weld has a concave or convex face, the size of the weld is really designated by the leg length of the largest isosceles triangle which will fit within the cross sectional contour of the weld.

The convex fillet weld causes an uneven distribution of stresses. On the other hand, the concave fillet weld minimizes the abrupt change of contour and gives better stress distribution, but it involves the deposition of excess metal. For most practical applications, the flat fillet weld or the concave fillet weld is used.

Table 8-7.—Weld characteristics.

Bead	Operating variables	Arc Sound	Resulting weld characteristics		
			Penetration—fusion	Burn-off of electrode	Appearance of bead
A	Normal amperes, normal volts, normal speed.	Sputtering hiss plus irregular energetic crackling sound.	Fairly deep and well defined.	Normal appearance.	Excellent fusion—no overlap.
B	Low amperes, normal volts, normal speed.	Very irregular sputtering, few crackles.	Not very deep nor defined.	Not greatly different from above.	On top of plate—not overlap such as is on bare rod.
C	High amperes, normal volts, normal speed.	Rather regular explosive sounds.	Deep-long crater.	Shielded arc coating is consumed at irregular high rate.	Broad rather thin bead—good fusion.
D	Low volts, normal speed, normal amperes.	Hiss plus steady sputter.	Small.	Coating too close to crater. Touches molten metal and results in porosity. Rod freezes.	Slits upon plate but not so pronounced as for low amperes. Somewhat broader.
E	High volts, normal speed, normal amperes.	Very soft sound plus hiss and few crackles.	Wide and rather deep.	Note drops at end of electrode. Flutter and then drop into crater.	Wide—splattered.
F	Low speed, normal amperes, normal volts.	Normal.	Crater normal.	Normal.	Wide bead—overlap large. Base metal and bead heated to considerable area.
G	High speed, normal amperes, normal volts.	Normal.	Small, rather well-defined crater.	Normal.	Small bead—undercut. The reduction in bead size and amount of undercutting depends on ratio of high speed and amperes.

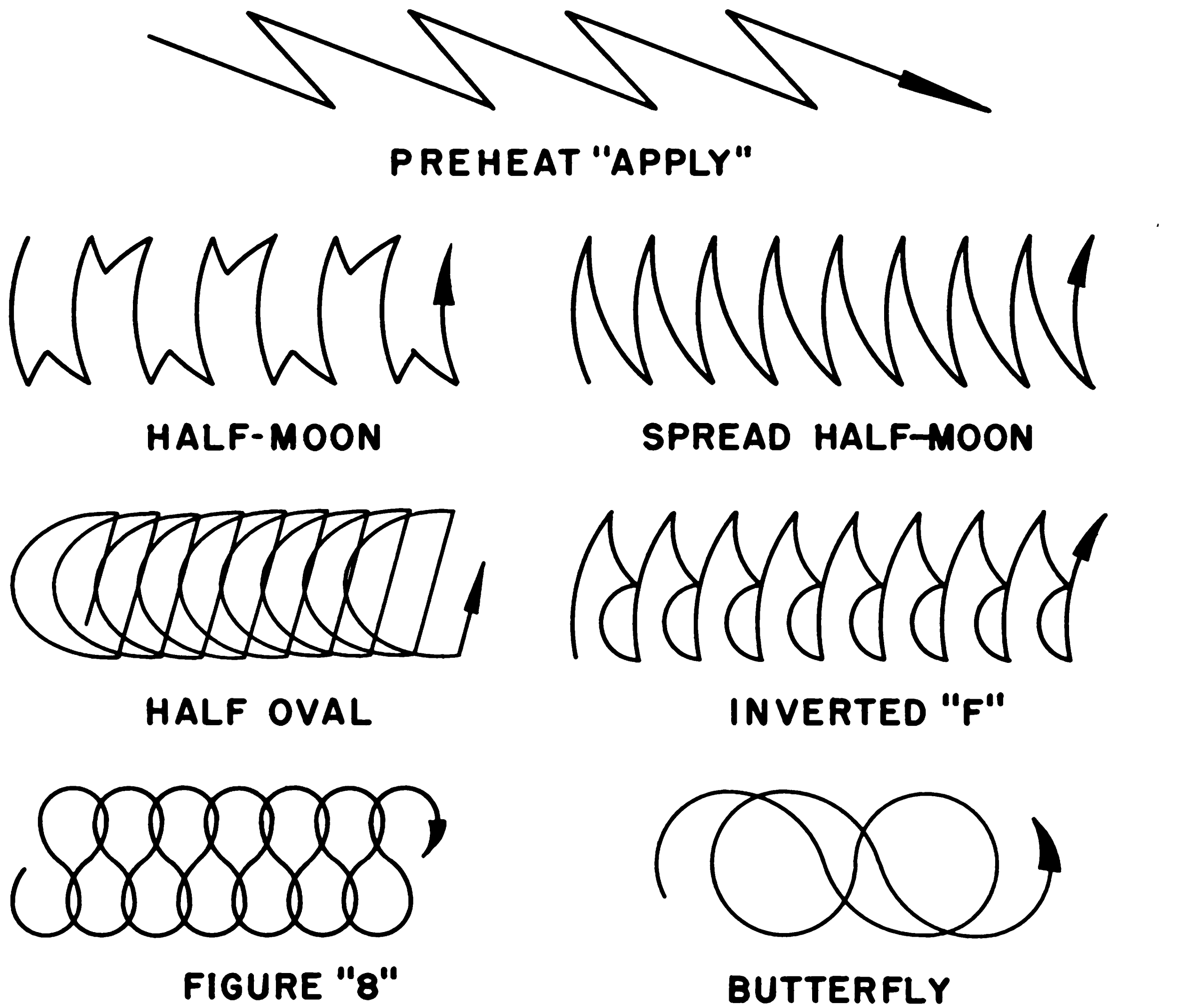


Figure 8-18.—Typical weaving techniques.

The correct size of a fillet weld can be determined most easily by the thickness of the thinnest sheet or plate being welded. The leg of a fillet weld should be equal in length to 1 1/2 times the thickness of the thinnest sheet or plate with the following reservation. When there is a wide variation between the thickness of the metal being welded, it is sometimes advisable to use the average thickness of the sheets. Instructions for using a butt and fillet weld gage are explained in figure 8-20.

TECHNIQUES OF POSITION WELDING

Each time the position of a welding joint or the type of joint is changed, it may be necessary to change any one or combination of the following: Current value, electrode, polarity, arc length, and welding technique.

Current values are determined by the electrode size as well as the welding position. Electrode size is governed by the thickness of the metal and the joint preparation, and the

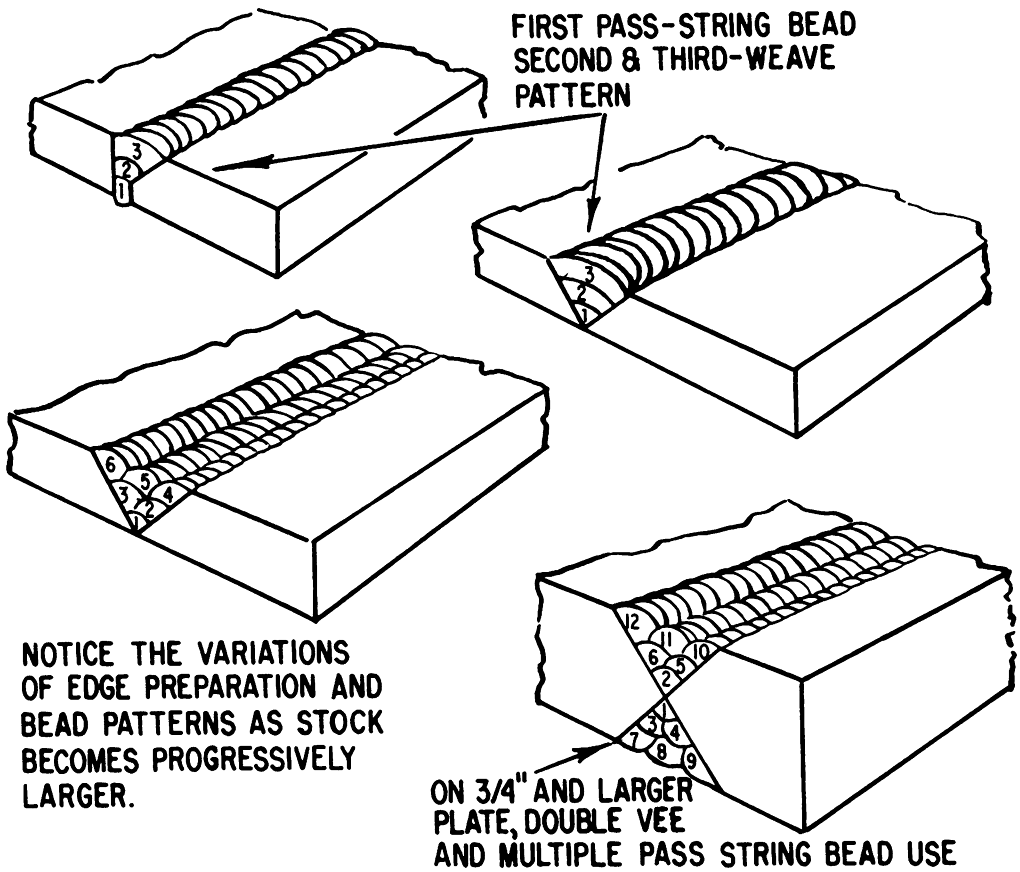


Figure 8-19.—Multiple pass groove welding of butt joints.

electrode type by the welding position. Manufacturers specify the polarity to be used with each electrode. Arc length is controlled by a combination of the electrode size, welding position, and welding current.

As it is impractical to cite every possible variation occasioned by different welding conditions, only the information necessary for the commonly used positions and welds is discussed here.

FLAT POSITION WELDING

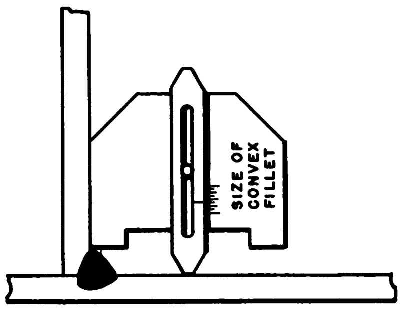
There are four types of welds commonly used in flat position welding. They are the bead, groove, fillet, and lap joint welds. Each type is discussed separately in the following paragraphs.

Bead Welds

Welding a square butt joint by means of stringer beads involves the same techniques as depositing stringer beads on a flat metal surface. Square butt joints may be welded in one, two, or three passes. If the joint is welded with the deposition of one stringer bead, complete fusion is obtained by welding from one side. If the thickness of metal is such that complete fusion cannot be obtained by welding from one side, the joint must be welded from both sides.

When the metals to be welded are butted squarely together, two passes are necessary. If the metals must be spaced, three passes are required to complete the weld. In the latter case, the third pass is made directly over the first and completely envelops it.

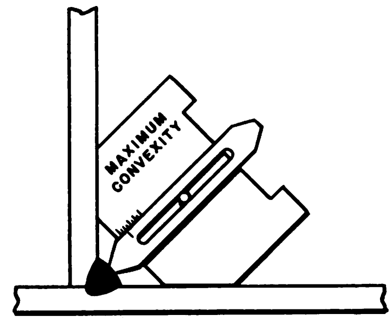
TO DETERMINE THE SIZE OF A CONVEX FILLET WELD



PLACE GAGE AGAINST THE TOE OF THE SHORTEST LEG OF THE FILLET AND SLIDE POINTER OUT UNTIL IT TOUCHES STRUCTURE AS SHOWN.

READ "SIDE OF CONVEX FILLET" ON FACE OF GAGE.

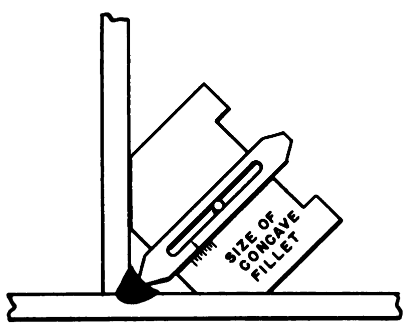
TO CHECK THE PERMISSIBLE TOLERANCE OF CONVEXITY



AFTER THE SIZE OF A CONVEX WELD HAS BEEN DETERMINED, PLACE THE GAGE AGAINST THE STRUCTURE AND SLIDE POINTER UNTIL IT TOUCHES THE FACE OF FILLET WELD AS SHOWN.

THE MAXIMUM CONVEXITY SHOULD NOT BE GREATER THAN THAT INDICATED BY "MAXIMUM CONVEXITY" FOR THE SIZE OF FILLET BEING CHECKED.

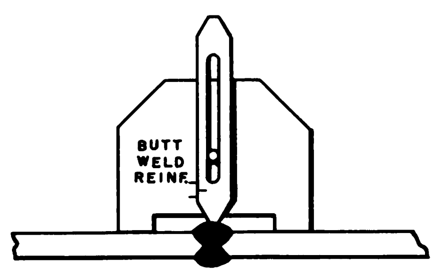
TO DETERMINE THE SIZE OF A CONCAVE FILLET WELD



PLACE GAGE AGAINST STRUCTURE AND SLIDE POINTER OUT UNTIL IT TOUCHES THE FACE OF THE FILLET WELD AS SHOWN.

READ "SIDE OF CONCAVE FILLET" ON FACE OF GAGE.

TO CHECK THE PERMISSIBLE TOLERANCE OF REINFORCEMENT



PLACE GAGE SO THAT REINFORCEMENT WILL COME BETWEEN LEGS OF GAGE AND SLIDE POINTER OUT UNTIL IT TOUCHES THE FACE OF WELD AS SHOWN.

THE PERMISSIBLE TOLERANCE OF REINFORCEMENT IS THAT INDICATED ON THE FACE OF GAGE.

AM.553

Figure 8-20.—Instructions for using butt and fillet weld gage.

It must be constantly kept in mind that beads, either the stringer or weaved type, are used to weld all types of joints. Even though the bead may not be deposited on the same type of surface, its action in the different welding positions and joints is basically the same as its action on the surface of flat metal. The same fundamental rules apply regarding electrode size and manipulation, current values, polarity, and arc lengths.

Bead welds can be made by holding a short arc and welding in a straight line at a constant speed, with the electrode inclined 5 to 15 degrees in the direction of welding. The proper arc can best be judged by recognizing a sharp cracking sound heard all during the time the electrode is being moved to and above the surface of the plate. Some of the characteristics of good bead welds are: They should leave very little spatter on the surface of the plate. The arc crater, or depression, in the bead when the arc has been broken should be approximately 1/16 inch deep. The depth of the crater at the end of the bead can be used as a measure of penetration into the base metal. The bead weld should be built up slightly, without any weld metal overlap at the top surface, which would indicate poor fusion. Figure 8-21 illustrates a properly made bead weld.

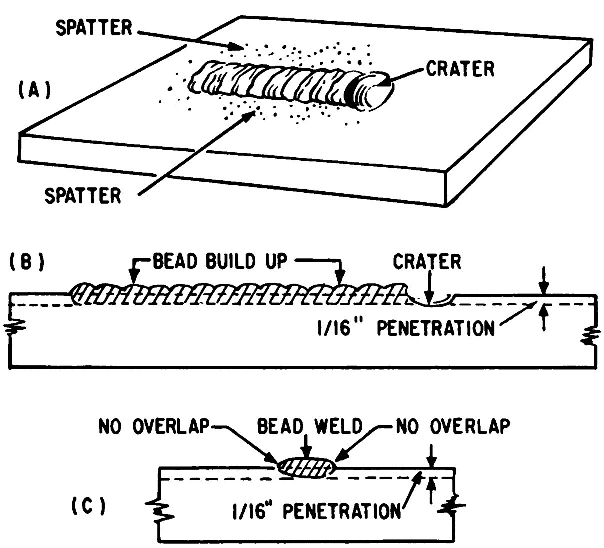


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Figure 8-21.—Properly made bead weld.

Groove Welds (Butt Joint)

Groove welding may be executed in either a butt joint or an outside corner joint. An outside corner joint corresponds to a single vee butt joint, and the same welding technique is used for both. It is for this reason that these two types of joints are classified under the heading of grooved welding. There are certain fundamentals which are applicable to groove welds, regardless of the position of the joint.

Groove welds are made on butt joints where the metal to be welded is 1/4 inch or more in thickness. Butt joints with a metal thickness of less than 1/4 inch require no special edge preparation and can be joined with a bead weld on one or both sides.

Groove welds are classified either single groove or double groove. This holds true whether the shape of the groove be a V, U, J, or any other form. Regardless of the position in which a single groove weld is made, it can be welded with or without a backing strip. If a backing strip is used, the joint may be welded from only one side. When a single groove weld is made without a backing strip, the weld may be made from one side, if necessary, although welding from both sides assures better fusion. The first pass of the weld deposit may be from either side of the groove. The first bead should be deposited to set the space between the two plates, and to weld the root of the joint. This bead, or layer of weld metal, should be thoroughly cleaned to remove all slag before the second layer of metal is deposited. After the first layer is cleaned, each additional layer should be applied with a weaving motion, and each layer should be cleaned before the next one is applied. The number of passes required to complete a weld is determined by the thickness of the metal being welded and the electrode size being used. As in bead welding, the tip of the electrode should be inclined between 5 and 15 degrees in the direction of welding.

Double groove welds are welded from both sides. This type of weld is used primarily on heavy metals to minimize distortion. This is best accomplished by alternately welding from each side—depositing a bead from one side and then from the other. However, this necessitates turning the plates over several times (6 times for 3/4-inch plate).

Distortion may be effectively controlled if the plates are turned over twice, as follows: Weld half the passes on the first side, turn the

:e over and weld all the passes on the second e, then turn the plates over and complete the ses on the first side.

The root of a double groove weld should be de with a narrow bead, care being taken to ire that the bead is uniformly fused into h root face. When a few passes have been de on one side, the root on the opposite side uld be chipped to sound metal to make the ove, and then welded with a single bead weld.

Any groove weld made in more than one pass st have the slag, spatter, and oxide carefully noved from all previous weld deposits before ceeding with the weld deposits over them. ure 8-22 shows some of the common types groove welds performed on butt joints in the position.

.et Welds

Fillet welds are used to make tee and lap ts. In welding tee joints in the flat position, two plates are placed to form an angle of degrees between their surfaces, as shown igure 8-23. The electrode should be held at angle of 45 degrees to the plate surface. The of the electrode should be tilted at an angle bout 15 degrees in the direction of welding. ht plates should be welded with little or no ving motion of the electrode, and the weld nade in one pass. Fillet welding of heavier es may require two or more passes. In that e, the second pass or layer is made with a nicircular weaving motion. In making the ve bead, there should be a slight pause at the of each weaving motion in order to obtain d fusion to the edges of the two plates with- undercutting them.

The procedure for making the lap joint fillet d is similar to that used for making the fillet d in a tee joint. The electrode should be d at an angle of 30 degrees to the vertical. top of the electrode should be tilted to an le of 15 degrees in the direction of welding. ure 8-24 illustrates a typical lap joint. The ving motion is the same as that used for tee ts, except that the hesitation at the edge of top plate is prolonged in order to obtain d fusion with no undercut. When welding es of different thickness, the electrode is d at an angle of 20 degrees to the vertical. e must be taken not to overheat and under- the thinner plate edge. The arc must be trolled in order to wash up the molten metal he edge of this plate.

OVERHEAD POSITION WELDING

The overhead position is one of the most difficult in welding, since a very short arc must be maintained constantly, in order to retain complete control of the molten metal.

The force of gravity tends to cause the molten metal to drop down or sag on the plate. If a long arc is held, the difficulty in transferring metal from the electrode to the base metal is increased, and large globules of molten metal will drop from the electrode and the base metal. The transfer of metal is aided by first shortening and then lengthening the arc. However, care should be taken not to carry too large a pool of molten metal in the weld. The procedures for making bead, groove, and fillet welds in the overhead position are discussed in the following paragraphs.

Bead Welds

For bead welds, the electrode should be held at an angle of 90 degrees to the base metal. In some cases, however, where it is desirable to observe the arc and the crater of the weld, the electrode may be held at an angle of 15 degrees in the direction of welding. Weave beads can be made by using the weaving motion. A rather rapid motion is necessary at the end of each semicircular weave in order to control the molten metal deposit. Care should be taken to avoid excessive weaving. This will cause overheating of the weld deposit and form a large pool of metal, which is hard to control.

Groove Welds (Butt Joints)

Overhead groove welds can be made more satisfactorily by using a backup strip. The plates should be prepared in a manner similar to that used for welding butt joints in the flat position. If no backup strip is used and the plates are beveled with a feather edge, the weld will burn through repeatedly, unless extreme care is used by the operator.

For overhead groove welding, bead welds are preferred to weave beads. Each bead deposited should be cleaned, and any rough areas should be chipped out before depositing the next bead. The electrode should not be too large, as this will prevent holding a short arc while obtaining good penetration at the root of the joint. The first pass should be made by holding the electrode at an angle of 90 degrees to the plate. The

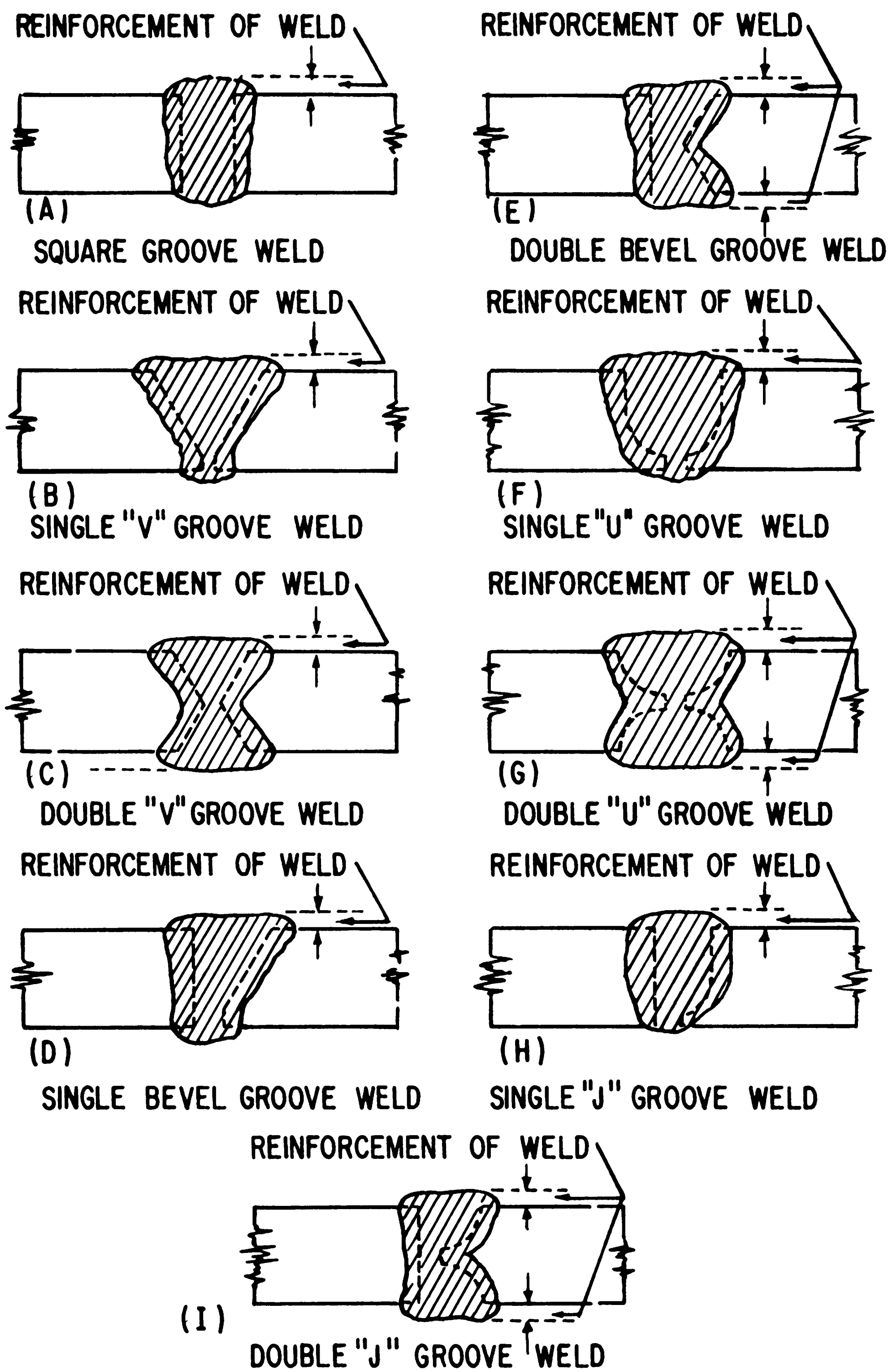

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Figure 8-22.—Groove welds on butt joints in flat position.

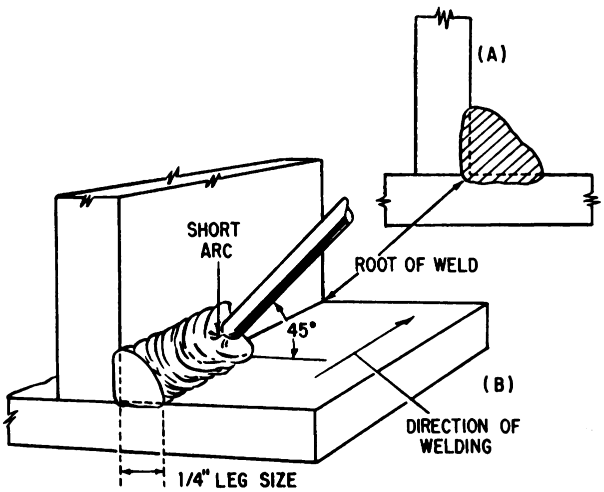

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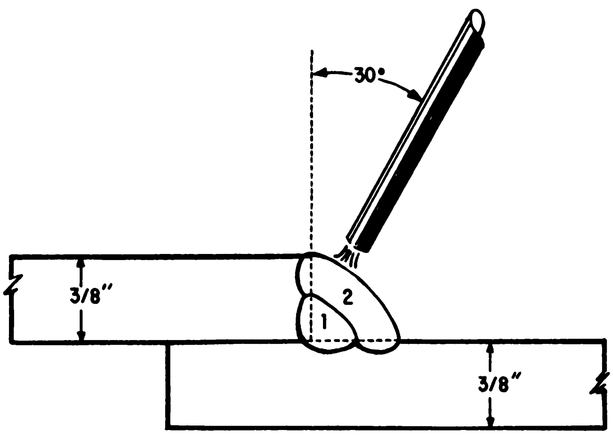
Figure 8-23.—Tee joint fillet weld.



AM.557
Figure 8-24.—Lap joint fillet weld.

use of excessive current should be avoided. An excess of current will create a very fluid puddle, making control of the puddle very difficult.

Fillet Welds

When making fillet welds on overhead tee or lap joints, a short arc should be held, and there should be no weaving of the electrode. The electrode should be held at an angle of about 30 degrees to the vertical plate, and moved uniformly in the direction of welding.

The arc motion should be controlled to secure good penetration to the root of the weld and good fusion with the sidewalls of the vertical and horizontal plates. If the molten metal becomes too fluid and tends to sag, the electrode should be whipped away quickly from the crater ahead of the weld in order to lengthen the arc and allow the metal to solidify. The electrode should then be returned immediately to the crater of the weld and the welding continued.

Welding on heavy plates requires several passes to make the joint. The first pass is a string bead with no weaving motion of the electrode. The second, third, and fourth passes are made with a slight circular motion of the end of the electrode, while the top of the electrode is held tilted at an angle of about 15 degrees.

VERTICAL POSITION WELDING

The vertical position, like the overhead position just discussed, is also more difficult than welding in the flat position. Due to the force of gravity, the molten metal will always have a tendency to run down. To control the flow of molten metal, a short arc is necessary, as well as careful arc voltage and welding current adjustments.

In metallic arc welding, current settings for welds made in the vertical position should be less than those used for the same electrode size and type on welds made in the flat position. The currents used for welding upward on vertical plate are slightly lower than those used for welding downward on vertical plate. The procedure for making bead, groove, and fillet welds in the vertical position are discussed in the following paragraphs.

Bead Welds

When making vertical bead welds it is necessary to maintain the proper angle between the electrode and the base metal in order to deposit a good bead. In welding upward the electrode should be held at an angle of 90 degrees to the vertical. When weaving is necessary, the electrode should be oscillated with a "whipping up" motion. In welding downward, bead welds should be made by holding the top end of the electrode at an angle of about 15 degrees below the horizontal to the plate with the arc pointed upward toward the oncoming molten metal. When a

weave bead is necessary, in welding downward, a slight semicircular movement of the electrode is necessary.

In depositing a bead weld in the horizontal plane on a vertical plate, the electrode should be held at right angles to the vertical. The top of the electrode should be tilted at an angle of about 15 degrees toward the direction of welding in order to obtain a better view of the arc and crater. The welding currents used should be slightly less than those required for the same type and size of electrode in flat position welding.

Groove Welds (Butt Joints)

Groove welding of butt joints in the vertical position is prepared in a manner similar to that used in welding butt joints in the flat position. In order to obtain good fusion with no undercutting, a short arc should be held, and the motion of the electrode should be carefully controlled.

Butt joints on beveled plates 1/4 inch in thickness can be groove welded by using a triangular weave motion. In groove welding butt joints in the horizontal position on identical plates, a short arc is necessary at all times. The first pass is made from left to right or right to left with electrode held at an angle of 90 degrees to the vertical plate. The second, third, and if required, any additional passes are made in alternate steps, with the electrode held approximately parallel to the beveled edge opposite to the one being welded.

Fillet Welds

When making fillet welds in either tee or lap joints in the vertical position, the electrode should be held at an angle of 90 degrees to the plates, or at an angle of up to 15 degrees below the horizontal, for better control of the molten puddle. The arc should also be held short to obtain good penetration, fusion, and molten metal control.

In welding tee joints in the vertical position, the electrode should be moved in a triangular weaving motion. The joint should be started at the bottom and welded upwards. A slight hesitation in the weave, as shown in figure 8-25, will improve sidewall penetration and allow good fusion at the root of the joint. If the weld metal should overheat, the electrode should be lifted away quickly at short rapid intervals without breaking the arc. This will allow the molten metal to solidify without running down. The electrode should be returned immediately to the crater of the weld, in order to maintain the desired size of the weld.

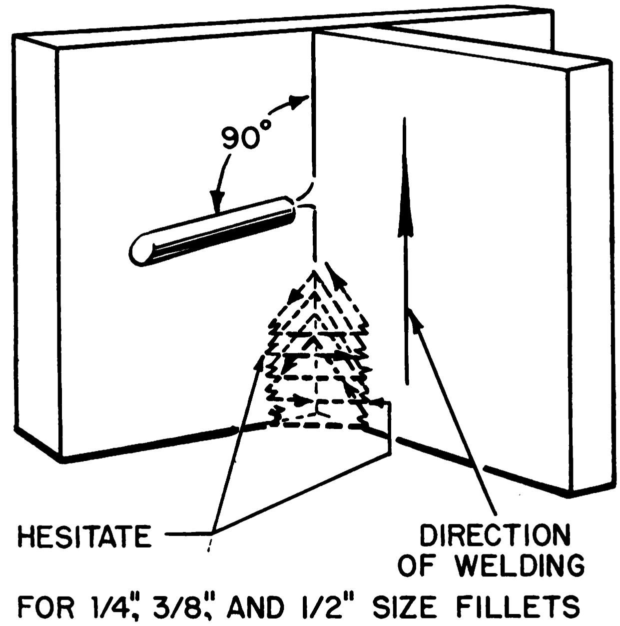


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Figure 8-25.—Vertical tee joint fillet weld.

When more than one layer of metal is needed to make a vertical tee weld, different weaving motions may be used. A slight hesitation at the end of the weave will result in good fusion without undercutting the plate at the edges of the weld. When welding lap welds in the vertical position, the same procedure is followed as that outlined for welding vertical tee joints, except that the electrode is directed more toward the one vertical plate. Care should be taken not to undercut either plate, or to allow the molten metal to overlap the edges of the weave. On heavy plate, lap joints require more than one layer of metal.

STANDARD WELDING SYMBOLS

The welding symbols shown in figure 8-26 have been developed and standardized by the American Welding Society. These symbols are used to supply necessary welding information

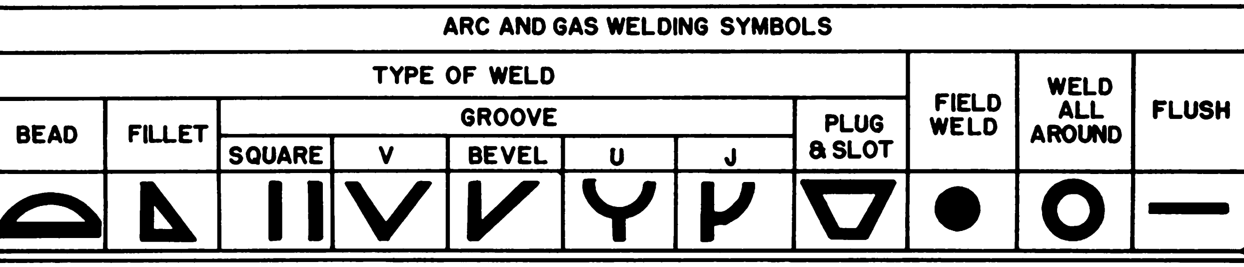

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Figure 8-26.—Standard welding symbols (arc and gas).

ı drawings and blueprints. Since it is not ·actical to illustrate every application in which ese symbols may be used, Blueprint Reading ıd Sketching, NavPers 10077-C, should be re- ewed.

SAFETY PRECAUTIONS

There are numerous safety precautions which ıould be observed when working with or around ectric arc welding equipment. Always make ·rtain that the welding cable and electrode holders are the correct size for the type machine being used, to avoid overheating. The power should be turned off when checking or performing maintenance on the welding machine. Never handle "live" electrical lines, even if they are insulated, with wet or oily gloves and always use the safety equipment provided for your protection. It is impractical to list all the safety precautions applicable to arc welding; therefore, the Arc Welding section of chapter 10 of NAVMAT P-5100, Safety Precautions for Shore Activities, should be reviewed prior to operating arc welding equipment.

CHAPTER 9

INERT-GAS SHIELDED ARC WELDING

Inert-gas shielded arc welding is a metal joining development which has become one of the Navy's most important welding processes, especially for aluminum and magnesium alloys and other hard to weld metals. Essentially, it is a process in which the metal to be joined is united by intense heat from an electric arc between a metal electrode and the work, while the electrode tip, arc, and molten puddle in the weld zone are shielded from the atmosphere by an envelope of inert (chemically inactive) gas, usually helium or argon.

There are two major types of inert-gas shielded arc welding. One variation is the tungsten inert-gas shielded arc welding process, commonly referred to as TIG welding. The TIG process employs a nonconsumable tungsten electrode and is particularly suited for welding thin gage metals less than 1/8 inch thick. The electrode does not burn off or supply metal to the joint. Necessary filler metal is added to the joint, as required, by the operator in a fashion similar to that used in oxyacetylene welding.

The second type is metal inert-gas shielded arc welding, commonly referred to as MIG welding. This process employs a consumable electrode in wire form and is fed continuously and automatically from a spool or reel through a flexible cable to the torch or electrode holder.

Of the two processes, TIG welding is more commonly used by ASH personnel. Therefore, most of this chapter is devoted to the TIG welding equipment and process. However, a brief description of the MIG welding equipment and process is covered in the following paragraphs.

A specially designed welding machine is required for MIG welding. It is a "Constant Voltage" (CV) type of machine. It can be a direct-current (d-c) rectifier or a motor or engine driven generator. The output welding power of this type machine has essentially the same voltage regardless of the welding current. Output voltage is regulated by a rheostat on the welding machine. The range is 15-40 volts, depending on the type of shielding gas used. (See table 9-1.) Open circuit voltage (while not welding) and arc voltage (while welding) are indicated on the machine's voltmeter. The constant voltage machine has no current control; therefore, it cannot be used for manual electrode welding.

The special wire feeder and the constant voltage machine are the heart of this process. A fixed relationship exists between the rate of electrode burnoff and welding current. At a given wire feed speed rate the machine will produce the current required to maintain the arc; consequently, the electrode wire feed rate determines the welding current. Wire feed speed is set by the control knob on the wire feeder. The welding current is indicated on the machine's ammeter (while welding) and ranges from approximately 100-800 amperes, depending on the diameter size of the electrode. (See table 9-2.) Direct current with reverse polarity (DCRP) is used for this process.

The MIG welding process uses a consumable electrode wire ranging in size from 0.030 to 1/8 inch. The sizes 0.030, 0.035, and 0.045 are referred to as microwire. The wire is solid and bare, except for a very thin copper coating on the surface to prevent corrosion. It contains deoxidizers to help clean the weld metal and to produce sound, solid welds. The wire should be carefully selected to assure the composition of the wire will have similar mechanical properties as the base metal.

The distance from the contact tip to the work is called STICKOUT. This distance is controlled by the weldor and should be 1/4 to 3/8 inch. The contact tip is recessed from 0 to 1/8 inch inside the cup or nozzle.

This process is used primarily for welding low and medium carbon steels, low alloys, and high strength steels of thin and medium thickness.

The kind of gas used depends on the metal being welded. Argon is used to weld aluminum and stainless steel, and carbon dioxide (CO_2) is used for the other steels mentioned above. When CO_2 is used it is referred to as a gas shielded arc welding process rather than an inert-gas shielded process. Carbon dioxide (welding grade) is the most widely used gas and, because of its low moisture content, its flow rate

Table 9-1.—Voltage settings for MIG welding.

Fillet size "S"	Position	Electrode		Deposit-approx. lb/ft	Gas flow cfh argon	Number of passes	Welding conditions DCRP		Travel-speed ipm
		Size (in.)	Feed (ipm)				Amps	Volts	
1/8"	Flat	3/64	195		36	1	130	20	26
	Horz. & Vert.	3/64	185		40	1	120	20	24
	Overhead	3/64	175		40	1	115	20	24
3/16"	Flat	3/64	260		30	1	195	20	24
	Horz. & Vert.	3/64	235		35	1	170	20	20
	Overhead	3/64	250		40	1	185	20	20
1/4"	Flat	1/16	200		40	1	230	21	21
	Horz. & Vert.	1/16	175		45	1	205	20	20
	Overhead	1/16	175		45	1	205	20	20
3/8"	Flat	1/16	280		45	3	305	22-27	30
	Horz. & Vert.	1/16	175		45	3	205	22-27	25
	Overhead	1/16	195		50	3	235	22-27	25

must be between 25 and 50 cubic feet per hour (cfh). In order to maintain this gas flow rate it might be necessary to manifold two cylinders together.

The torch receives and guides the electrode wire into a proper position for the welding operation. The wire is fed from the spool or reel through the drive unit and flexible cable to the torch. This cable is independent of the multiple conductor through which the torch receives welding current, gas, and water.

The torch is either water or air cooled, depending on the amperage used. Normally the torch is ambient air cooled up to 500 amperes when CO_2 gas shielding is employed.

Figure 9-1 illustrates MIG welding equipment.

The outstanding features of the CO_2 process are: (1) higher welding speed, (2) high metal deposition rates, (3) deep penetration, (4) greater production.

The body protection and safety precautions are the same as other types of arc welding.

Unlike all other methods of fusion welding, both the TIG and MIG welding processes are capable of making clean, sound welds without

Table 9-2.—Ampere settings for MIG welding.

Material thickness	Electrode		Deposit approx. lb/ft	CO_2 Gas Flow cfh	Welding conditions DCRP		Reactance	Travel speed ipm
	Size in.	Feed ipm			Amps.	Volts		
18 Ga. - 0.050"	0.045	360	0.010	35	300	26	Yes	190
16 Ga. - 0.062"	0.045	360	0.013	35	325	26	Yes	150
14 Ga. - 0.078"	0.045	360	0.017	35	325	27	Yes	130
1/8"	1/16	200	0.026	35	380	30	No	80
3/16"	1/16	260	0.036	35	425	31	No	75
1/4"	3/32	150	0.077	35	500	32	No	45
3/8"	3/32	205	0.189	35	550	34	No	25
1/2"	1/8	160	0.294	35	625	36	No	23
5/8"	1/8	175	0.411	35	675	36	No	18

the use of corrosive fluxes. This makes the inert-gas shielded processes particularly desirable for aircraft welding. Many assemblies constructed of aluminum, magnesium, titanium, and corrosion-resisting steels cannot be welded by any other method, because of the impossibility of removing fluxes from inaccessible places after welding.

TUNGSTEN INERT-GAS SHIELDED ARC WELDING

Tungsten inert-gas shielded arc (TIG) welding is a gas-arc welding process which uses an inert gas to protect the weld zone from the atmosphere. Heat for welding is provided by a very intense electric arc which is struck between a virtually nonconsumable tungsten electrode and the work. The principle of the inert arc is the same as the conventional electric arc discussed in the preceding chapter. The arc is actually the passage of electricity through atmospheric resistance between the electrode and the bare metal. The current used may be either a.c. or d.c., depending on the material to be welded.

This process differs from metallic arc welding in that the electrode is not melted and used as a filler metal. On joints where filler metal is required, a filler rod is fed into the weld zone and melted with the base metal in much the same manner as used with oxyacetylene welding.

In any type of welding, the best obtainable weld is one that has the same chemical, metallurgical, and physical properties as the base metal. To obtain these conditions, the molten weld puddle must be protected from the atmosphere; otherwise, atmospheric oxygen and nitrogen will combine readily with the molten weld metal and result in a weak, porous weld. In inert arc welding, the weld zone is shielded from the atmosphere by an inert gas which is fed through the torch. Either of two inert gases may be used, argon or helium. An arc in argon or helium gas is smooth and quiet. In argon the

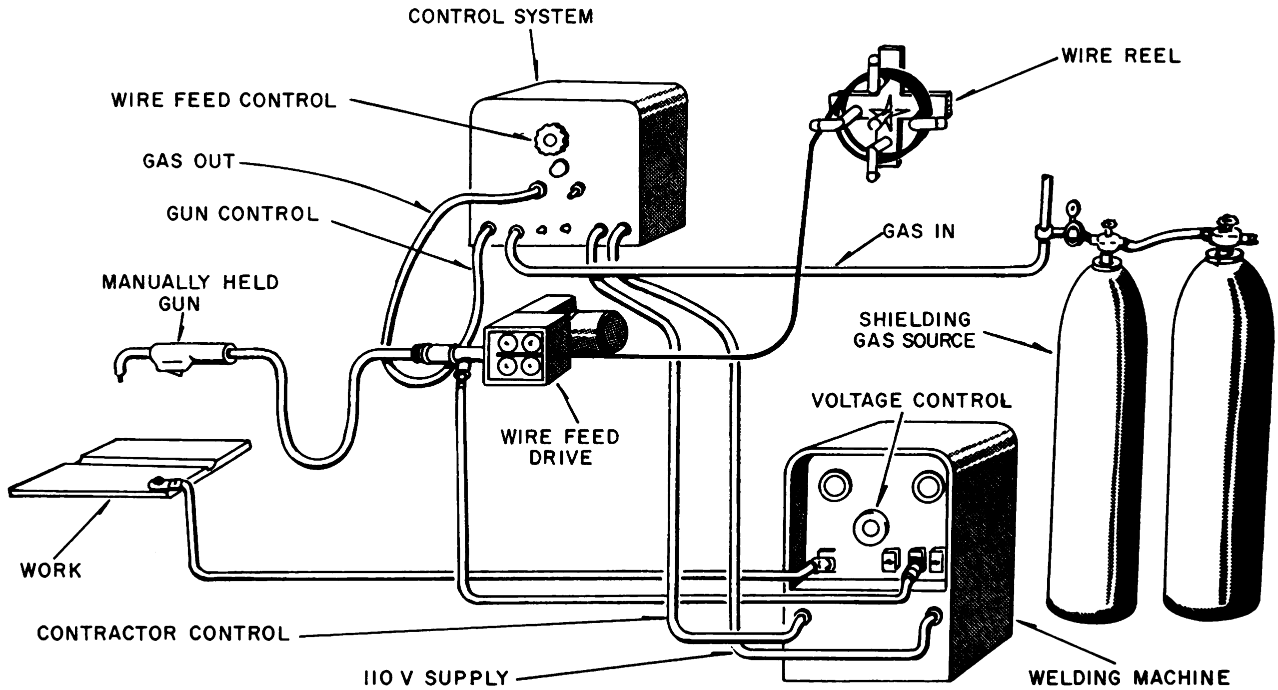

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Figure 9-1.—MIG welding equipment.

arc has an appearance similar to the oxyacetylene welding flame. In helium the arc is more ball-like in shape.

The TIG welding process has several advantages over the conventional arc welding process; and it also has some disadvantages which are discussed in the following paragraphs.

ADVANTAGES

Welds are stronger, more ductile, and more corrosion-resistant than welds made by the conventional arc welding process. The weld zone has 100 percent protection from the atmosphere; therefore, no flux is required. It is applicable to a wider variety of joints and no post-weld cleaning is required. Since no flux is required, it eliminates flux or slag inclusions in the weld and there are no sparks, fumes, or spatter. Little or no filler metal is needed.

Efficient use is made of welding current; the machine operates only during actual welding operations, with a-c power. Other advantages are high speed, 3 to 12 inches per minute, with a minimum of distortion; efficient use of welding heat; and smooth, even welds with excellent strength and in some cases with only slight reinforcement.

DISADVANTAGES

Different types of machines and currents are required for different materials to be welded. For example, alternating current high frequency (ACHF) is used for welding aluminum; while direct current straight polarity (DCSP) is used for heavy gage stainless steel. The initial cost of equipment is high and the gases used are expensive.

APPLICATION

As previously mentioned, the TIG welding process can be used to weld most metals; particularly the hard to weld metals such as aluminum, magnesium, corrosion-resistant steels, titanium, nickel, and nickel-base alloys. This process is also used widely for welding various

combinations of dissimilar metals, and for applying hard-facing and surfacing materials to steel.

EQUIPMENT REQUIREMENTS

TIG welding equipment is produced by many manufacturers, and there are as many equipment designs as there are manufacturers. For this reason it is very important to remember when studying this chapter that the equipment being discussed is only one of the many types that might be found throughout the Navy. However, the functions of similar component parts of different makes of machines are identical although they may not appear to be so.

Basic equipment requirements for TIG welding consist of the torch plus additional apparatus to supply electric power, inert gas, and water. (See fig. 9-2.)

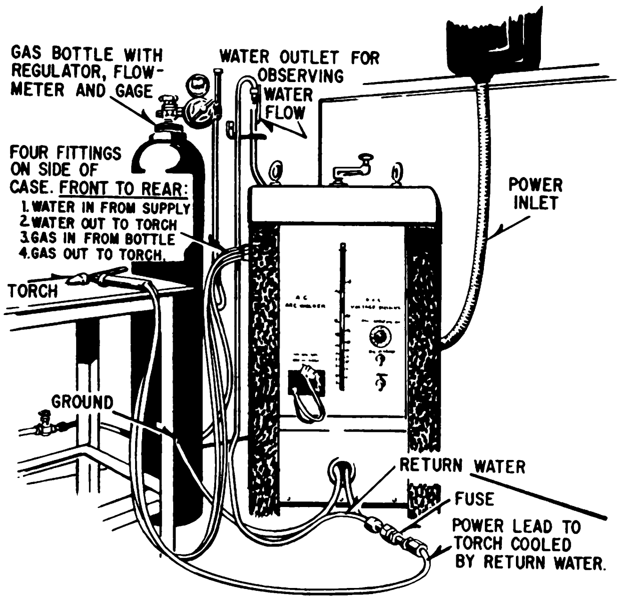

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Figure 9-2.—Typical TIG welding equipment.

The torch feeds both the welding current and the inert gas to the weld zone. The current is fed to the weld zone through the electrode which is held firmly in place by the electrode holder. The inert gas is fed to the weld zone through a gas cup which screws on the end of the torch.

Power Unit

The power unit supplies alternating current through a transformer, or direct current through a motor generator. The type of current used depends largely on the material to be welded. The power source for operating a direct-current (d-c) welder can be supplied by any standard motor-driven generator with adequate amperage capacity for the job. Best results are obtained with an open circuit voltage of not more than 80 volts.

For a-c welding power, any standard transformer with an adequate amperage capacity for the job may be used. For best results the open circuit voltage should be from 60 to 100 volts, and the transformer should be a balanced wave type. Regular a-c power for TIG welding should have high-frequency current for stabilizing the welding arc. When high-frequency current is used, a normally open foot or torch switch is recommended to shut off this current before the torch is withdrawn from the weld. This prevents formation of a line arc that, with the gas protection removed, might cause oxidation and crater cracks in the weld metal.

In direct-current welding, the welding current circuit can be hooked up as either straight polarity or reverse polarity. The machine connection for direct-current straight polarity welding is electrode negative and work positive. For direct-current reverse polarity the connections are reversed and the electrode is positive and the work negative.

In straight polarity welding, the electrons, hitting the workpiece at high velocity, exert a heating effect on the plate; while in reverse polarity welding, just the opposite occurs. The electrode has to absorb the extra heat, which tends to melt off the end of the electrode. Therefore, reverse polarity requires a larger electrode diameter than straight polarity. For example, a 1/16-inch diameter pure tungsten electrode can handle 125 amperes of welding current with straight polarity. If the polarity was reversed, this amount of current would melt off the electrode and contaminate the weld. A 1/4-inch diameter electrode is required to handle 125 amperes of reverse polarity current safely.

Hand Welding Torches

There are various types of TIG welding torches available and, although not all torches

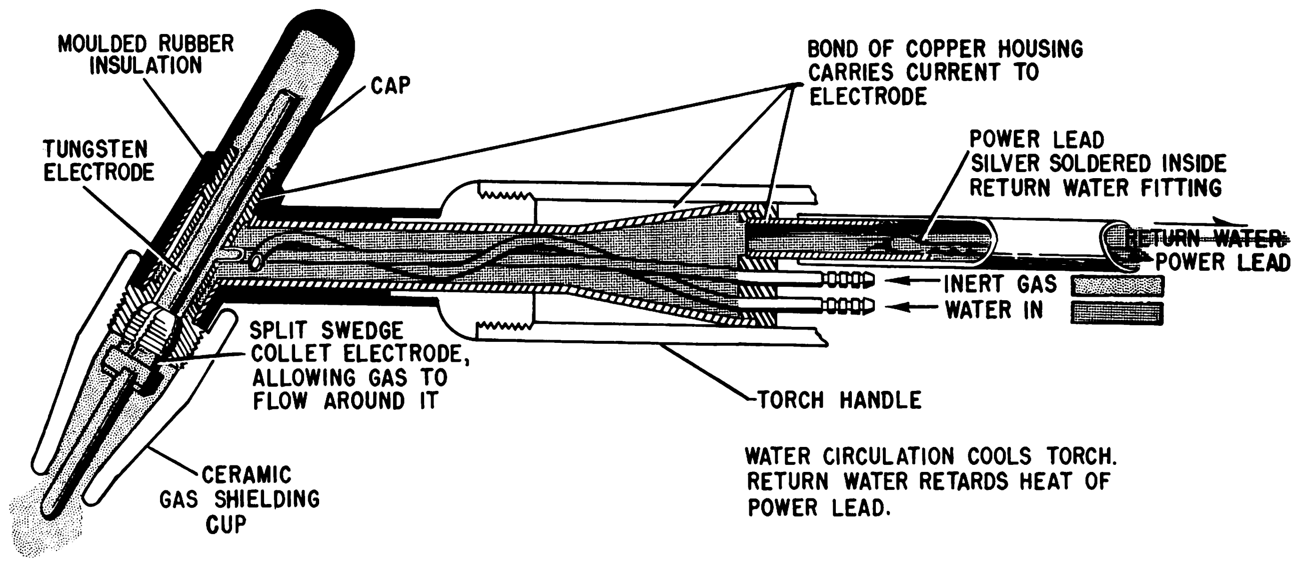

Figure 9-3.—Typical water-cooled TIG welding torch.

have the same external appearance, their principle of operation is much the same. Figure 9-3 shows a schematic of a typical water-cooled TIG welding torch. The torch illustrated is designed to perform several functions: (1) hold the electrode; (2) introduce an envelope of shielding gas around the electrode; (3) transmit current to the electrode; and (4) circulate cooling water throughout the holder.

The water-cooled torch is designed for TIG welding using either alternating current or direct current with straight or reverse polarity. Gas enters through a hose fitted to the rear of the handle, passes through the body of the torch, and emerges from the gas orifice in the torch head. Gas is then guided down toward the weld puddle by the shielding gas cup which surrounds the electrode.

Cooling water circulates through the torch and out around the power cable. The water cooling protects parts of the torch from excessive heat and permits the use of a minimum of insulation in the body of the torch. The torch is light and easy to manipulate.

The power cable is contained in the water discharge hose, and is water-cooled in such a manner that extremely high currents can be used without excessive power loss.

CAUTION: Be sure water lines are hooked up properly. Do not weld with water flow reversed. The water should cool the torch body before it flows over the power cable.

The torch is fully insulated to safeguard the operator against shock, and to prevent damage to the work from accident arcing. Overheating of the torch, due to failure of the water supply, is prevented by a special fuse inserted in the cable circuit section of the water discharge line. Standard 3-ampere, 250-volt links can be used. Two fuse links must be used to accommodate maximum amperage capacity of the torch. Use of the torch at high amperages tends to deteriorate the shielding gas cup.

Tungsten electrodes for TIG welding are available in three types: pure tungsten (99.9 percent), 1 percent thoriated tungsten, and 2 percent thoriated tungsten. These electrodes have a very high melting point and are practically nonconsumable—normal consumption is 0.001 to 0.005 inch per hour.

The electrode, particularly in manual operations, will pick up contamination from the work caused in most cases by touching the workpiece. The life of the electrode can be extended by making sure that the electrode does not come in contact with the work during welding operations,

and by choosing an electrode of the proper size for the current range being used. The electrode will deteriorate more rapidly when the welding current is too high or too low for the particular size electrode being used.

If the electrode comes in contact with the workpiece or worktable, a small bead or ball will appear at the contact end. This causes the arc to become unstable. This ball may be removed by grooving the electrode just above the fouled point with a file, then breaking it off with pliers. It is essential that the electrode be grooved to prevent splitting when the burned metal is broken off. This operation can be repeated as often as necessary until the electrode can no longer be clamped or held in the torch.

Electrodes are available in 3- to 12-inch lengths and 0.020- to 3/8-inch diameters. The diameter of the electrode to be used is determined by the current. The current is governed by the type and thickness of the material to be welded. Table 9-3 gives the recommended current ranges for nonthoriated and thoriated electrodes. The electrodes are held in place by a collet (fig. 9-3). Electrode length is adjusted by extending or retracting the electrode through the collet clamping device.

NOTE: Select an electrode which is well within the current range being used.

Ceramic and Metal Cups

Ceramic and metal cups are available in various sizes. The type and size of the cup, in most cases, depend on the size of the electrode and the current to be used. Table 9-4 shows

Table 9-3.—Recommended current ranges for nonthoriated and thoriated tungsten electrodes (HW-18 torch).

Welding Currents, Amp.				
High-frequency alternating current*		Direct-current straight polarity	Direct-current reverse polarity	Electrode diameter (inch)
(Using pure tungsten electrodes)	(Using thoriated tungsten electrodes)	(Using pure tungsten or thoriated electrodes)	(Using pure tungsten or thoriated electrodes)	
5-15	5-20	5-20		0.020
10-60	15-80	15-80		0.040
50-100	70-150	70-150	10-20	1/16
100-160	140-235	150-250	15-30	3/32
150-210	225-325	250-300	25-40	1/8

*The maximum current values shown in the table for high-frequency alternating current have been determined using an unbalanced wave transformer. If a balanced wave transformer is used, either reduce the maximum values in the table by about 30 percent or use the next larger size electrode. This is necessary because of the higher heat input to the electrode in a balanced wave setup.

NOTE: All current values are metered readings. Most transformers deliver about 15 percent more current than shown on their scale readings.

Table 9-4.—Recommended gas cup sizes for the HW-10 and HW-18 torches.

Electrode diameter (inch)	Hand Welding HW-10 and HW-18 Torches			
	Ceramic Cups Max. Rating		Metal Cups Max. Rating	
	250 amp. AC-DC		300 amp. AC-DC	
	HW-10	HW-18	HW-10	HW-18
0.020		4-5		4
0.040	4	4-5	4	4-5
1/16	4-5	4-5-6	4-5	4-5-6
3/32	6-7	6-7	5-6	5-6-7-8
1/8	6-7-8		6-7-8	6-7-8-10-12

the recommended gas cup sizes for the HW-10 and the HW-18 torches. Ceramic cups are acceptable when the welding current is less than 250 amperes. When higher currents are used, or when welding conditions are usually severe, metal cups are used. Metal cups should never be allowed to come in contact with the workpiece when the current is on.

Regulator

The regulator used on the inert-gas cylinder is identical in design to those used on oxygen cylinders. It is ruggedly built, and combines high sensitivity of control with a large flow capacity.

CAUTION: Always stand to the side when cracking the cylinder valve. Gage faces sometimes blow out when pressure is suddenly applied.

The function of the regulator is to reduce the high pressure in the cylinder to the desired working pressure, and hold that pressure without fluctuation or readjustment, until the cylinder is almost exhausted. Figure 9-4 shows a typical regulator, flowmeter, and pressure gage combination.

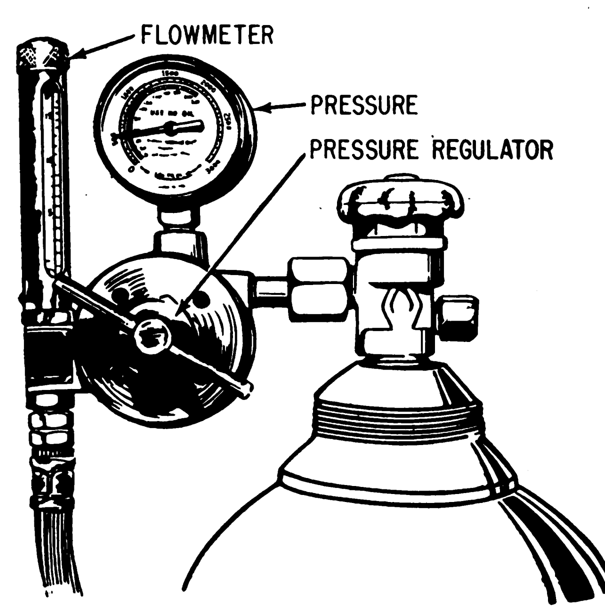

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Figure 9-4.—Regulator, flowmeter, and pressure gage.

Flowmeter

Along with pressure reduction, successful inert-gas shielded arc welding requires a constant flow of shielding gas. The gas flow rate is indicated by a graduated glass tube flowmeter (fig. 9-4). As shown, the flowmeter is usually attached to the regulator, but it may be installed elsewhere in the gas line. Be sure you have the proper flowmeter for the gas being used or the flow indicated will be incorrect.

Flow is regulated by a needle valve of special design, and is measured by the position of the lightweight metal spinner inside a graduated glass tube. Flowmeters are calibrated in liters per minute (lpm) or cubic feet per hour (cfh). The selection of gas flow is a critical factor. A sufficient flow of gas is required during the welding operation to prevent oxidation of the weld metal. The weld zone must have 100 percent protection from the atmosphere. This flow will be found in the range of 4 to 15 liters per minute for argon, and 8 to 40 liters per minute for helium.

The exact flow setting will depend on the type of joint, fit of the joint, and the material to be welded. Small differences in conditions can make considerable difference in the required flow. The distance the torch is held from the work will change the required flow sharply. A drafty shop will increase the required flow. An increase in welding speed, while generally acting to reduce gas consumption, will usually require an increase in gas flow. The flowmeter should be mounted vertically.

Inert Gases

The inert gases used in the inert-gas shielded arc welding processes are argon or helium. An inert gas is defined as a gas that will not combine chemically with any known substance.

Whether the gas used in inert-gas shielded arc welding is helium or argon, the gas must be of high purity and free of moisture, hydrogen, and hydrocarbons. While both argon and helium are used interchangeably, and in some instances have been mixed, each gas has advantages for certain applications.

Argon's density (weight per volume) is considerably greater than that of helium, but it offers less resistance to the passage of electricity than does helium. Because of the difference in electrical resistance, the heat produced by the arc in an atmosphere of helium is hotter than that developed in argon. The helium-shielded arc also produces deeper penetration, but at the same time has a greater tendency to spatter. Because of its greater density, argon remains in the weld vicinity longer and provides a better cleaning action when welding aluminum and magnesium with alternating current. For these reasons, about one-third less argon than helium is needed to provide equal shielding.

Commercial argon has certain advantages over commercial helium in this process; therefore, it is used to a greater extent. Commercial argon is available in 99.8 percent purity, this purity being far above any commercial standard for helium.

The cylinders used for storing argon and helium are similar to those used for oxygen and acetylene. Each cylinder has a 242 cubic-foot capacity, and is charged to approximately 2,200 psi.

Almost pure shielding gas is required in inert-gas shielded arc welding. Since any impurities in the cylinder will have a tendency to settle to the bottom, cylinders should always be replaced when the pressure in the cylinder reaches 25 psi.

Helium is stored in cylinders painted gray with two orange bands at the top. Cylinders containing argon are also painted gray but have one white band at the top. The same care should be exercised in handling, setting up, and storing argon and helium cylinders as those prescribed for oxygen and acetylene cylinders.

Water-Gas Shutoff Valves

Shutoff valves for water and gas are of two types, solenoid and manual. The solenoid valve is controlled electrically. The manual valve is shut off by hanging the torch on the hook provided on the valve. A water drain or recirculating system is necessary to carry away the water coming from the cooling system of the torch.

Gas should be permitted to flow after the arc is broken for a minimum of 5 seconds to a maximum of 40 seconds, depending on the diameter of the electrode. The electrode should be brought to a silvery-white appearance, without blue-black discoloration, which indicates oxidation.

PROTECTIVE EQUIPMENT

The protective equipment used for inert-gas shielded arc welding is similar to that used in

electric arc welding. The operator should be properly protected from the arc rays. This requires suitable clothing to cover all exposed skin surfaces, and a welder's helmet with the proper shade of glass to protect the eyes and face. The recommended welding glass numbers for various welding applications are given in chapter 8, table 8-2 of this manual.

SETTING UP AND ADJUSTING EQUIPMENT

In most cases TIG welding machines are delivered from the factory ready for installation in the shop. However, they must be set up and adjusted, making it necessary for shop personnel to be familiar with the important units on the machine and the power requirements. The manual supplied with the machine should be consulted in setting up and adjusting the machine. Some of the general requirements are discussed in the following paragraphs.

Power Requirements

For alternating-current welding, a single-phase transformer requiring a 220- or 440-volt, alternating-current supply is generally used. The power from the machine to the electrode and work is supplied through two terminals on the machine, marked GROUND and ELECTRODE. Always make certain that the welding cable attached to the torch is connected to the terminal marked ELECTRODE.

It is recommended that the welding cables be kept as short as possible to keep the dissipation of the high-frequency current to a minimum. If the welding cables are lying close together, or on a steel plate, the high frequency may in time break down the insulation on the welding cables, thereby weakening the high-frequency output at the welding arc.

For direct-current welding, a motor-generator unit powered by a 220- or 440-volt, 3-phase alternating-current supply is generally used. Like the alternating-current machine, two terminals located on the machine supply the power to the torch and work. One terminal is marked POSITIVE and the other NEGATIVE. However, unlike the a-c machine, the torch on the d-c machine may be connected to either terminal, depending upon the polarity to be used. It should be noted, however, that straight polarity is used in almost all cases.

Special Control Units

Several special control units have been developed to control automatically various phases of the welding process. Included among these units are a contactor unit which controls gas, water, and power automatically; a unit to shut off the high-frequency power; and a unit to shut off the welding power. These units may be used singly or in combinations, and their use conserves gas and water, reduces radio interference, and provides greater convenience in operation.

Water Coolant

The water coolant is required to protect parts of the torch and cable circuit from overheating. The water can run continuously, but it is more convenient to have either a manually controlled valve or an electrically controlled solenoid valve. A solenoid valve can also be used to control the gas and should be connected in parallel with the water solenoid valve.

Various torches are designed for different current ranges, and the amount of water required for adequate cooling will vary. To insure that the torch is adequately cooled, always check the manufacturer's specifications for the proper pressure and temperature of the water to be used to cool the torch and cable circuit.

High-Frequency Unit

The high-frequency unit of the TIG welding machine is used to introduce a high-voltage, high-frequency, low-power additional current into the welding current. The high frequency produces a low-intensity arc, which jumps the gap between the electrode and the workpiece and pierces the oxide film, forming a path for the welding current to follow.

Introducing this high-voltage, high-frequency current into the welding current gives the following advantages:

1. The arc can be started without touching the electrode to the work.
2. Better arc stability is obtained.
3. A longer arc is possible.
4. The tungsten electrodes will have a longer life.
5. Use of wider current ranges for a specific diameter electrode is possible.

The high-frequency unit of a TIG welder is controlled by a switch located on the front of

the machine. Welders which are designed to supply alternating current have a two-position switch. In the OFF position there is no high frequency and in the CONTINUOUS position the high frequency remains on as long as the contactor is depressed.

Welders which are designed to supply either alternating or direct welding current have a three-position switch. The third position is the START position. The START position is used when welding with direct current; high frequency is used in this position only to help start the arc. In the START position the high frequency will shut off automatically as soon as the arc is initiated. For TIG welding with direct current, the high frequency switch may be used in the START or CONTINUOUS position.

When using the TIG welder for regular arc welding the high frequency is not required, and the switch should be in the OFF position.

The output of the high-frequency unit is controlled by the high-frequency rheostat. The highest position provides the greatest high-frequency output and the greatest distance at which the high frequency will establish and maintain an arc from the tungsten electrode to the work. Once the electrode is hot, the jumping distance of the arc from the electrode to the work will increase, as both heat and high voltages ionize the inert gases used in the welding process.

Welding Current Controls

The welding current is controlled by various methods. The current for the TIG welder illustrated in figure 9-2 is controlled by a handcrank on top of the housing. An indicator, visible through a slot in the front of the machine, indicates the current output.

Other welders have several current ranges which are selected by moving a lever to the desired range. On these machines, current control rheostats are generally used for fine adjustments within the selected range.

The current settings for TIG welding depend on the size of the electrode, speed of travel, thickness of material, and the amount of heat dissipation into surrounding jigs and fixtures.

TIG welders designed to produce both direct and alternating welding current have a current selector. This selector has an alternating-current high-frequency stabilized (ACHF), a direct-current straight polarity (DCSP), and a direct-current reverse polarity (DCRP) position.

NOTE: On some machines the high frequency is not automatically selected along with the alternating current. On these machines the selector must be set to the a-c position and a manually operated switch must be actuated to provide the high frequency.

The type of current used depends on the type of metal to be welded. Alternating-current high frequency (ACHF) is generally recommended for aluminum and magnesium. Direct-current straight polarity (DCSP) is used for all other materials. Direct-current reverse polarity may be used, as needed, when the machine is being operated as a regular arc welder without the use of shielding gas. DCRP is seldom used with TIG.

Inspection and Lubrication

The interior of the welder should be inspected and cleaned at least once a year. Accumulations of dirt and dust can be best removed by using compressed air.

Occasional lubrication of the threaded shaft and sliding mechanism of the moving coil is essential, especially when the unit is in continuous service. The grease used should have a high melting point and should be evenly distributed on threads of shaft and guides. Use grease sparingly to protect the windings of the coils from lubricating material.

Safety Precautions

There are several general precautions that should be observed when operating TIG welding machines. All adjustments made on the inside of the machine must be in accordance with the maintenance manual for the machine concerned. Make certain that the external power source is shut off since dangerous voltage exists in all parts of the machine unless the power circuit is DISCONNECTED. All protective clothing should be worn and the proper shade lens should be used in the welding helmet.

High-frequency current used in this process can cause deep painful puncture wounds. The operator is more subject to shock when using a-c power. Make certain rubber floor mats are kept in place and the operator remains on the mat at all times when welding.

Insulation on the power lead should be in good condition and the water hose should be checked frequently for leaks. A leaky water hose is very dangerous. Beware of the hazards

of hot metal and unsafe equipment. Remember a clean shop is a healthy shop.

WELDING PROCEDURES AND TECHNIQUES

Before setting up for a job, make a check on the equipment needed. In general, the items listed below will fill the bill for most jobs.

A-c or d-c welding machine.
Inert arc torch.
Source of running water.
Source of inert gas.
Hose.
Regulator (single or double stage).
Water flowmeter or visible flow of water.
Tungsten electrodes of suitable size (polished).
Gas cups for corresponding sizes of electrodes.
Protective clothing.
Leather gloves.
Head shield with proper shade lens.
Rubber floor mat.
Pliers and tongs.
Clamps, backing plates, or jigs.
Extra fuses.
Filler rods, if required.

After material and equipment are assembled and set up in a welding booth or curtained area, the next step is to select the right type of current to be used, as shown in table 9-5. However, it should be kept in mind that figures given in any table in this chapter are to be used only as a basis from which to work. The actual settings for best results can be obtained only through experience.

Aluminum and Aluminum Alloys

The TIG welding process is particularly adapted to the welding of aluminum and aluminum alloys. Sound welds may be made without the use of flux. Dispensing with flux is a definite advantage since flux removal from aluminum welded joints is extremely important to avoid corrosion. Although all of the aluminum alloys except 2024 and 7075 are considered weldable by the inert-gas shielded arc process, there are certain restrictions, as described in the following paragraphs.

EFFECTS OF WELDING.—The heat of welding decreases the strength of both the nonheat-treatable and heat-treatable aluminum alloys except when the alloy is in the annealed condition. In some cases, the resistance to corrosion is also lowered.

The effects of strain hardening in the nonheat-treatable alloys are partially or wholly destroyed by heat, depending upon the temperature attained coupled with the time at temperatures above 400°F. These alloys are not affected as far as corrosion resistance is concerned.

The effects of solution heat treatment and precipitation treatments for heat-treatable aluminum alloys are adversely affected by the heat of welding. The extent increases with temperature and time at temperature above 400°F. The alloys containing substantial amounts of copper (alloys 2014 and 2017) suffer not only from loss of strength but also from loss in resistance to corrosion when subjected to the heat of welding.

In view of the above, heat-treatable aluminum alloys that have been welded must be properly reheat treated before being used on aircraft. Heat treating after welding dissolves soluble constituents in the weld metal and all of the coarse and fine precipitated particles in the base metal. A more homogenous condition results throughout the material. Quenching retains this solid solution condition while subsequent precipitation, at room temperature or at a moderately elevated temperature when artificial aging is employed, takes place fairly uniformly in the form of finely divided particles. Thus, the maximum strengths and resistance to corrosion of the base metal are realized. There is a sacrifice in ductility, however, and the strength of the joint is dependent upon that of the cast material in the weld zone.

NOTE: Alloys 2024 and 7075 are not fusion welded because of hot cracking and impairment of corrosion resistance. However, both of these alloys are spot and seam welded extensively.

CURRENT REQUIREMENTS.—Current requirements for the most commonly used metals are shown in table 9-5. As shown in the table, first preference for aluminum is high-frequency stabilized alternating current.

The low-intensity arc produced by this high-frequency current provides a path easily followed by the main welding current. The welding arc can be started easily without the electrode actually contacting the work, and a longer arc can be used during welding. With alternating current stabilized in this manner, good welds can be made.

Current range (amperage) depends upon the size electrode, thickness of the metal, and the

Table 9-5.—Selecting the right type of current.

Material	High-frequency stabilized alternating current	Direct current	
		Straight polarity	Reverse polarity
Magnesium up to 3/16 inch	1	N. R.	1
Magnesium above 3/16 inch	1	N. R.	N. R.
Magnesium castings	1	N. R.	2
Aluminum	1	N. R.	N. R.
Aluminum castings	1	N. R.	N. R.
Stainless steel 0.015 to 0.050 inch	1	2	N. R.
Stainless steel 0.050 inch and up	2	1	N. R.
High-carbon steel 0.015 to 0.050 inch	1	N. R.	N. R.
High-carbon steel 0.050 inch and up	2	1	N. R.
Cast Iron	2	1	N. R.
Brass alloys	1	1	N. R.
Everdur	2	1	N. R.
Monel	2	2	N. R.
Silver	2	1	N. R.
Hastelloy alloys	1	2	N. R.

1. Excellent operation—first preference.
2. Good operation—second preference.

N. R. —Not recommended.

type of joint to be welded. Table 9-6 lists the general operating data for aluminum.

TORCH ADJUSTMENT.—The correct size electrode and corresponding gas cup are selected according to the thickness of the material to be welded.

The electrode should be polished with steel wool before installing it in the torch. Cleaning of the electrode is important since the appearance of the finished weld is improved by the cleanliness of the electrode.

Install the electrode in the torch so that the extension is 1/8 to 3/16 inch beyond the end of the gas cup for butt welding and 1/4 inch for fillet welding. ALWAYS MAKE CERTAIN THAT THE WELDING CURRENT IS OFF BEFORE ADJUSTING THE ELECTRODE.

SELECTION OF FILLER ROD.—The selection of the proper filler rod is necessary in order to obtain a weld of high strength and good corrosion resistance. For alloys 1100 and 3003, 1100 filler rod may be used. For other aluminum alloys, 4043, 5154, 5356, or 5456 rod should be used.

PREPARATION OF METAL.—Cleanliness is very important. Parts to be welded should be free of oil, grease, and dirt. Combustible materials in the path of the arc will burn and contaminate the inert-gas shielding. If filler rod is used, it should also be cleaned.

Table 9-6.—General operating data for aluminum.

Aluminum				
Thickness (inch)	Current range (amperes)	Argon flow (cubic feet per hour)	Rod size where required (inches)	Arc speed (inches per minute)
0.025	10-75	10	1/16	10-40
0.031	20-75	10	1/16	10-40
0.0375	35-75	10	1/16	10-40
0.050	50-125	14	3/32	10-40
0.0625	70-130	14	3/32	10-40
0.078	80-150	14	1/8	10-40
0.109	150-175	14	1/8	20-30
0.125	160-200	14	3/16	6-25
0.195	175-200	14	3/16	4-20
0.250	150-200	20	3/16	2-10
0.375	150-225	25	3/16	2-8
0.500	300-450	30	1/4	5-10

Oil or grease should be mechanically or chemically removed. An abrasive disc sander is recommended for mechanical cleaning. Chemical cleaning should be performed, using a caustic bath followed by a sulfuric acid brightening bath. Do not use a wire brush or nitric acid, as this will contaminate the weld.

STARTING THE ARC.—When alternating current with high-frequency stabilization is being used, it is possible to start the arc without actually contacting the work. Grasp the torch in a comfortable position. Hold the torch in a horizontal position about 2 inches above the work, or starting block, then quickly swing the torch down toward the work or starting block, so that the end of the electrode is 1/8 inch above the work, or starting block. This motion will start the arc. Figure 9-5 illustrates the procedure for starting the arc.

The downward motion should be made rapidly to provide the maximum amount of gas protection to the weld zone. If the end of the electrode is too far from the work when the arc starts, it will cause oxidation of the weld.

In direct-current welding, the same motion is used for starting the arc; however, the electrode must touch the work in order for the arc to start. As soon as the arc is started, withdraw the electrode approximately 1/8 inch above the work to avoid contaminating the electrode in the molten puddle.

The arc can be started with a-c or d-c power on the work itself or on a heavy piece of copper or scrap steel and then carried to the starting point of the weld. Do not use a carbon block for starting the arc, as the electrode will become contaminated, causing the arc to wander.

In making the first start with a-c power with a cold electrode, the distance the arc will start is much shorter than when the electrode is hot. When starting to weld with a hot electrode, the motions must be rapid, as the arc tends to start before the torch is in the proper welding position. This procedure for starting the arc can

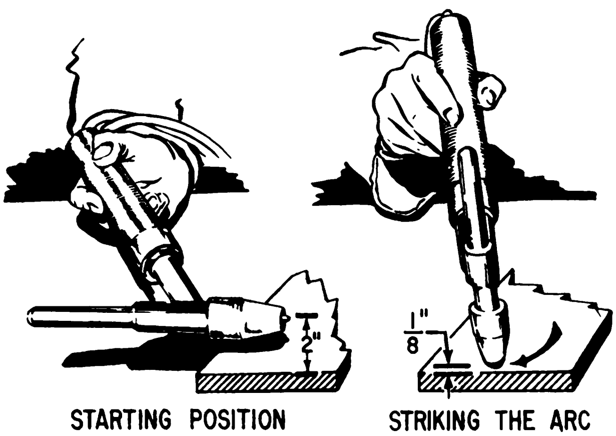

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Figure 9-5.—Starting the arc.

be used on all types of materials to be joined by the TIG welding process.

BREAKING THE ARC.—To stop the arc, merely snap the electrode rapidly back to the horizontal position, as shown in figure 9-6. This motion is just the reverse of the starting procedure.

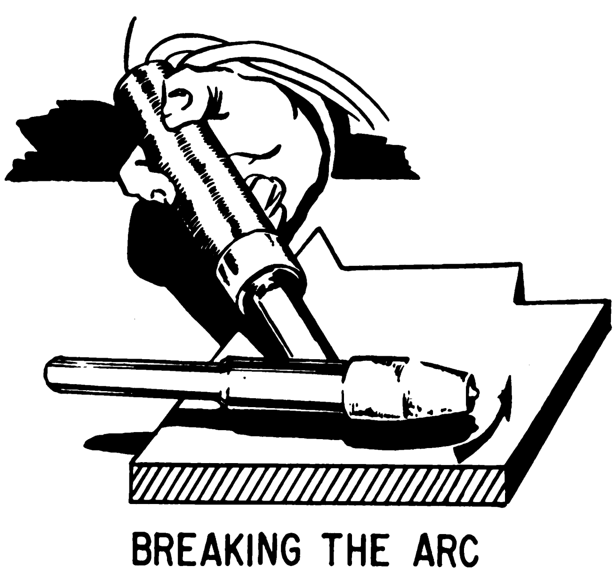

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Figure 9-6.—Breaking the arc.

This motion must be fast so that the arc will not mar or damage the weld surface or work. When the electrode is hot the arc will jump a greater distance. This procedure for breaking the arc can be used on all types of materials.

ARC BLOW.—With the torch held stationary, the points at which the arc leaves the electrode and strikes the work may often shift and waver without apparent reason. This is known as arc blow, and is generally caused by one of the following reasons:

1. Low electrode current density—amperage for the electrode diameter is too low.
2. Carbon contamination on the electrode—caused by starting the arc on a carbon block.
3. Magnetic effects—caused usually by improper location of the ground.
4. Air drafts—in excessive air drafts, the arc becomes erratic.

The first two causes are distinguished by a very rapid movement of the arc from side to side. The third cause will usually displace the arc along the entire length of the weld. The fourth will cause various amounts of arc wandering, depending on how severe the air drafts are.

PREHEATING.—It is possible to weld aluminum up to 3/4 inch thick by hand without preheating. However, thicknesses over 3/4 inch will require a preheat of 300° to 400°F.

By preheating, the operator can work more easily and complete the weld faster. Preheating can be accomplished in special preheat ovens or by gas flames directed on the work in such a manner that they do not disturb the inert-gas shield.

WELDING PROCEDURE.—After the arc has been started, hold the torch at an angle of approximately 75 degrees to the surface of the work. The starting point on the work is first preheated by moving the torch in a small circular motion until a molten puddle 3 to 5 times the thickness of the material is developed.

The end of the electrode should be held approximately 1/8 inch above the work. When the puddle becomes bright and fluid, move the torch slowly and steadily along the joint at a speed which will produce a bead of uniform penetration and width. No oscillating or other movement of the torch except for a steady motion forward is required.

When filler rod is required, the rod is held at an angle of approximately 15 degrees to the work, and just clear of the arc stream. Once the puddle has been developed, move the torch

to the rear of the puddle, and add filler rod by quickly touching the leading edge of the puddle. Add only a small amount of rod. Remove the rod and bring the torch back up to the leading edge. When the puddle is again bright, repeat the above steps.

Arc speed is governed by the amount of current and thickness of material. Speed should be adjusted to obtain a bead of uniform height and width. The penetration should be uniform on the underside of the work. Good penetration is indicated by a very small, smooth bead. The controlling factors affecting a good weld are as follows:

1. Torch angle.
2. Arc length.
3. Arc speed.
4. Electrode condition.
5. Joint design.

Some of the precautions to observe when running the bead follow. No attempt to add filler rod should be made until the puddle has been developed. Do not insert the filler rod in the arc stream or considerable spatter and excessive melting of the filler rod will result. Do not attempt to hold the filler rod in the molten puddle. The amount of filler rod determines the buildup of the bead, and little or no buildup is necessary.

INSPECTION OF WELD.—Inspection of the finished weld is very important not only to make certain that it meets all specifications but also to determine if the proper welding procedures were used. Some possible defects in the weld and their probable causes are:

1. Bead too narrow—usually indicates an excessive rate of welding speed.
2. Bead too wide—usually indicates too slow a rate of welding speed.
3. Weld contamination—indicated by a black deposit on the weld and caused by the electrode coming in contact with the weld metal.
4. Oxidation of the weld—caused by an insufficient supply of inert gas.

Magnesium Alloys

Magnesium alloys in virtually all forms can be successfully welded by the TIG welding process without the use of flux. Since this method requires no flux, all types of joints commonly employed on steel can be used on magnesium.

There are, however, some types of magnesium alloys which have poor weldability and are welded only when emergency repairs are necessary. In table 9-7 the relative weldability of the standard magnesium alloys is summarized briefly. These weldability ratings are very general, since design, fabrication, and serviceability factors dictate the choice of alloy.

CURRENT REQUIREMENTS.—Both direct-current reverse polarity and alternating current with high-frequency stabilization can be used for TIG welding of magnesium alloys. The selection of either a-c or d-c power for welding magnesium alloys is largely dependent upon the thickness of the material to be welded.

Direct-current reverse polarity is suitable for thin materials. On heavier sections, multipass welding is required in most cases due to shallow penetration. Alternating current with high-frequency stabilization is recommended for the welding of magnesium greater than 3/16 inch in thickness. Table 9-8 contains the general operating data for magnesium.

TORCH ADJUSTMENT.—The proper size electrode and corresponding gas cup is determined by the thickness of the material to be welded. The electrode extension should be the same as that previously given for aluminum and aluminum alloys.

SELECTION OF FILLER ROD.—Magnesium alloy filler rod is used and should be of the same chemical composition as the material being welded. It is necessary to use the recommended filler rod for best results. Filler rod is available in a variety of alloys and diameters. Select the correct diameter rod according to the thickness of the material to be welded.

PREPARATION OF METAL.—Cleaning of magnesium is necessary before welding, and can be accomplished by either chemical or mechanical means. For chemical cleaning, a solution of chromic acid and sodium nitrate can be used. Mechanical cleaning can be accomplished with steel wool, abrasive cloth, or a power-operated wire brush. Edges to be welded should be smooth and free from loose pieces or pits which might contain any contamination such as oil, grease, or dirt.

WELDING PROCEDURE.—The same method recommended for starting and stopping the arc previously discussed in the section on aluminum can be used on magnesium. The average arc length should be 1/8 inch when using helium and 1/16 inch or less when using argon. A short arc length must be used to produce a bright, shiny weld. Longer arcs will leave the weld surface dark and cloudy in appearance. To obtain maximum penetration with a-c power, the

Table 9-7.—Relative weldability of magnesium alloys.

Alloy	Form	Arc welding	Remarks
AZ91C	Sand castings.	B	Welding used for repairs and to wrought products.
AZ92A	Sand and permanent mold castings.	C	Welding used chiefly for repairs.
AZ63A	Sand and permanent mold castings.	D	Welding used chiefly for repairs.
AZ81A	Sand and permanent mold castings.	B	Welding used for repairs and to wrought products.
EK30A	Sand and permanent mold castings.	A	Welding used chiefly for repairs and to wrought products.
EK41A	Sand and permanent mold castings.	A	Welding used chiefly for repairs and to wrought products.
EZ33A	Sand and permanent mold castings.	A	Welding used chiefly for repairs and to wrought products.
HK31A	Sand and permanent mold castings.	A	Welding used chiefly for repairs and to wrought products.
HZ32A	Sand and permanent mold castings.	B	Welding used chiefly for repairs and to wrought products.
AZ91A & AZ91B	Die castings.	E	Emergency repair welding only due to porosity.
AZ31B	Extrusions. Sheet.	A A	
AZ61A	Extrusions.	A	
M1A	Extrusions.	A	
AZ80A	Extrusions.	B	
ZK60A	Extrusions.	E	Limited weldability.
HK31A	Sheet and plate.	A	Excellent welding characteristics.

A—Excellent B—Good C—Fair D—Poor E—Very Poor

Table 9-8.—Data for TIG welding of magnesium.

laterial ickness inches)	Number of passes	Welding current* in amperes		Electrode diameter (inches)		Welding rod diameter (inches)	Gas flow (cu ft/min)	
		AZ31B	M1A	a-c	d-c		Argon	Helium
).040	1	35	45	3/32	3/32	1/8	0.2	0.4
).064	1	50	60	3/32	1/8	1/8	0.2	0.4
).081	1	65	80	1/8	1/8	1/8	0.2	0.4
).102	1	85	100	1/8	3/16	1/8	0.3	0.5
).128	1	100	115	1/8	3/16	5/32	0.3	0.6
).188	1	140	160	3/16	5/16	5/32	0.3	0.6
).188	2	100	100	1/8	3/16	5/32	0.3	0.6
).250	1	180	200	3/16	3/8	3/16	0.3	0.8
).250	2	115	125	1/8	1/4	5/32	0.3	0.6
).375	1	250	270	3/16	—	3/16	0.4	0.8
).375	2	140	160	3/16	5/16	3/16	0.3	0.8
).500	2	310	330	1/4	—	3/16	0.4	0.8
).750	2	420	450	5/16	—	1/4	0.6	1.2

rent values given for welding with a backing plate and for making fillet welds. Slightly lower rent values used for welding without a backing plate and for making corner or edge joints.

:trode should be flush or slightly below the face of the work. Accidental touching of the face with the electrode will not tend to cause stick as in the welding of other metals.

The torch should be held with the electrode pendicular to the work and the filler rod as rly parallel with the weld surface as possi- The weld should progress in a straight line ıg the weld seam at a uniform rate of speed hat an even bead is deposited. A weaving or ıry motion is not recommended.

The filler rod can be fed either continuously intermittently. To avoid oxidation, the rod ıld not be withdrawn from the inert-gas eld during welding. The end of the rod should touch the leading edge of the puddle. As the torch is moved along, small bits of the rod melt off. No dipping motion of the rod is necessary. With alternating current in welding magnesium, it is desirable to start and stop the arc with a torch switch or open foot switch to prevent oxidation caused by drawing a long arc.

STRESS RELIEVING.—After welding, magnesium should be stress relieved. The temperature for stress relieving varies from 265° to 500°F, depending on the alloy. The soak time also varies from 15 minutes to 1 hour, depending on the alloy. When stress relieving, avoid overheating.

INSPECTION OF WELDS.—All welds should be inspected for penetration and defects. Improper penetration is indicated by a fine line on the reverse side of the weld. This condition can be prevented by slightly beveling the underside of the pieces to be welded. The bevel will let molten weld metal float away oxides formed by heat as it flows down between the sheets.

If cracks appear at the ends of a weld, try preventing recurrence by butting pieces of the same material as that being welded against each end of the joint, clamping them in place until the weld is completed.

Corrosion-Resistant (Stainless) Steel

As described in chapter 6, the most popular stainless steels contain approximately 18 percent chromium and 8 percent nickel. Types 302, 303, 304, 316, 321, and 347 are probably the most extensively used 18-8 steels.

All of the above stainless steels can be satisfactorily welded by the TIG process. The one serious difficulty encountered is intergranular corrosion of the metal in or alongside the weld in certain of these steels.

When an 18-8 stainless steel with more than 0.08 percent carbon is heated between 1,000° and 1,500° F, the excess carbon is precipitated or segregated out of solution and deposited along the grain boundaries in the form of carbides. These carbides are less resistant to corrosion than is the parent metal.

In making a weld, the metal deposited and the joint itself are heated to the melting or fusing temperature, which is approximately 2,690° F, while the body of the work remains cold. Hence, there is a zone parallel to and near the weld which is heated between 1,000° and 1,500° F. It is in this area that carbides are precipitated. This region may be wide or narrow; near or some distance from the weld, depending upon the type of joint and method of welding. If welding is rapid, the zone will be narrow and close to the weld; if slow, it will be wide and farther away.

This carbide can be put into solution again by heating to a temperature of approximately 1,900° F or higher and cooling fast through the critical range. Table 9-9 lists the recommended postweld heat treatments for the most commonly used steels. It should be noted that alloys 304L, 316L, 321, and 347 require no postweld treatment. Alloys 304L and 316L have a lowered carbon content (0.03 percent maximum), alloy 321 has titanium added, and alloy 347 has columbium added. When either of these procedures is employed, the steel is virtually free from intergranular attack.

Table 9-9.—Recommended postweld heat treatments for stainless steels.

AISI Type	Recommended heat treatment
301 302	Cool rapidly from 1,950° — 2,100° F when corrosion conditions are moderate to severe.
304	Cool rapidly from 1,850° — 2,000° F only when corrosion conditions are severe.
304L	Not required for corrosion resistance.
316	Cool rapidly from 1,950° — 2,100° F only when corrosion conditions are severe.
316L	Not required for corrosion resistance.
321, 347	Not required for corrosion resistance.

CURRENT REQUIREMENTS.—Either direct-current straight polarity or high-frequency stabilized alternating current may be used in welding stainless steels by the TIG process. Slightly greater penetration and welding speed can be obtained with direct current, and high-frequency alternating current has a tendency to cause hot tearing or stress cracks in or near the weld. Direct-current straight polarity is therefore considered first preference. Table 9-10 lists the general operating data for welding stainless steels.

TORCH ADJUSTMENT.—The proper size electrode and corresponding gas cup is determined by the thickness of the material to be welded. The electrode should extend about 1/8 inch below the gas cup in most applications. It is important to select the correct size as it is difficult to start and maintain the arc with an oversized electrode.

Table 9-10.—General operating data for stainless steels.

Stainless Steel				
Thickness (inch)	Current range (amperes)	Argon flow (cubic feet per hour)	Rod size (inches) (where required)	Arc speed (inches per minute)
0.025	20-40	10	1/32	15-40
0.031	20-40	10	1/32	15-40
0.0375	50-130	10	1/16	15-40
0.050	80-165	10	1/16	15-40
0.0625	90-170	10	1/16	15-40
0.078	125-200	10	3/32	15-40
0.109	140-250	10	3/32	10-35
0.125	150-275	10	1/8	10-30
0.195	100-225	10	1/8	-----
0.250	400-500	10	3/16	12-20
0.375	400-500	10	3/16	*7-14
0.500				

* 2 passes.

SELECTION OF FILLER ROD.—Filler rods for general-purpose welding usually have the same composition as the base metal. Strips cut from parent metal may be used in some cases.

For maximum strength and corrosion resistance, a special type filler rod must be used. Detail information on these special types of filler rods can be found in Specification MIL-R-5031B.

PREPARATION OF METAL.—As with all other materials to be welded with this process, corrosion-resistant steel must be clean. Parts to be welded must be free from oil, grease, or dirt. The surface to be welded may be cleaned either by chemical or mechanical means as previously discussed in this chapter.

WELDING PROCEDURE.—After starting the arc, the torch should be held at an angle of approximately 75 degrees to the work to run the bead. When filler rod is used, it should be held at an angle of approximately 10 degrees to the work. The length of the arc should be approximately 1/8 inch.

The procedure for manipulating the torch is basically the same as that used for other materials. The puddle is developed and the rod is dipped rapidly in and out of the forward edge of the puddle. Care must be taken not to pull the filler rod too far from the puddle. A cold filler rod chills the puddle and makes it difficult to maintain. Dipping in and out of the puddle rapidly will assure the addition of filler metal at a uniform rate to form a weld with good contour.

WELD-BACKUP.—For TIG welding applications on corrosion-resisting steels, the joint should be backed up. On light gage materials, backing is used to protect the underside of the weld from atmospheric contamination which results in poor surface appearance. On heavier

materials, it prevents the weld puddle from dropping through by drawing away some of the heat.

Some of the materials used for weld-backup are: metal backup bars; inert-gas shielding; a combination of metal backup bars and inert-gas shielding; and fluxes.

On applications where the final weld composition must conform to rigid specifications, extra care must be taken to exclude all atmospheric oxygen from the underside of the weld. There are a number of gases and methods of applying them that will give 100 percent protection of the weld zone.

INSPECTION OF WELD.—Good weld penetration is indicated by either the oxide deposit (color bands) or a small smooth bead on the underside of the work. A finished weld should have a regular bead pattern and may require some cleaning. Cleaning can usually be accomplished by wire brushing.

CHAPTER 10

STRUCTURAL MAINTENANCE AND REPAIR

As related in the five preceding chapters, one important responsibility of the ASH is the structural maintenance and repair of ground support equipment. Many of the tools and items of hardware described in chapter 5 are used primarily in this maintenance responsibility. Likewise, the different metals and the shop equipment discussed in chapter 6 are vital to the structural repair of support equipment. Of course, oxyacetylene, electric arc, and inert-gas arc welding, discussed in chapters 7, 8, and 9, respectively, are necessary for the repair of some structural members. It may be necessary to refer to some of these subjects while studying this chapter, which describes some of the structural repairs required by the ASH.

Riveting procedures, the installation of lap and flush patches, and the repair and installation of turnlock fasteners are described in the first part of this chapter. Next is a discussion on the repair of bodies and fenders. This is followed by discussions on the maintenance and repair of steam cleaners and dry honers. The last part of the chapter is devoted primarily to the inspection and load testing of hoisting equipment.

RIVETING PROCEDURES

The ASH must use his knowledge, ability, and experience when planning a structural repair. This does not end after the proper materials have been selected. Each type of rivet must be selected and driven in a precise manner to meet riveting specifications. Some of the riveting specifications are rivet spacing and edge distance, diameter of rivet hole, the size of the rivet bucktail, and in some instances the smoothness of the surface. These can be accomplished only through determination, practice, and accurate manipulation of all standard layout and riveting equipment.

RIVET SELECTION

The following rules govern the selection and use of rivets in making a repair:

1. Replacements must not be made with rivets of lower strength material unless they are larger than those removed. For example, a rivet of 2024 aluminum alloy should not be replaced by one made of 2017 aluminum alloy unless the 2017 rivet is a size larger. Similarly, when 2117 rivets replace 2017 rivets, the next size should be used.
2. When rivet holes become enlarged, deformed, or otherwise damaged, use the next larger size as replacement.
3. Countersunk-head rivets are to be replaced by rivets of the same type and degree of countersink.
4. The proper length of a rivet is an important part of the repair. Should too long a rivet be used, the formed head will be too large, or the rivet may bend or be forced between the sheets being riveted. Should too short a rivet be used, the formed head will be too small or the riveted material will be damaged. The length of the rivet should equal the sum of the thickness of the metal plus 1 1/2 times the diameter of the rivet, as shown in figure 10-1. The formula for determining rivet length is specified as follows:

$$1\,1/2\,D + G = L$$

where D = rivet diameter, G = grip (total thickness of material), and L = total length of rivet.

When using tinner's rivets, refer to table 10-1 as a guide for selecting rivets of the proper size for the different gages of sheet metal.

SPACING AND EDGE DISTANCE

RIVET SPACING, also referred to as RIVET PITCH, is the distance between rivets in the same row, and is measured from rivet center to rivet center. TRANSVERSE PITCH is the distance between rows of rivets and is measured from rivet center to rivet center. EDGE DISTANCE is the distance from the center of the rivet to the edge of the material being riveted.

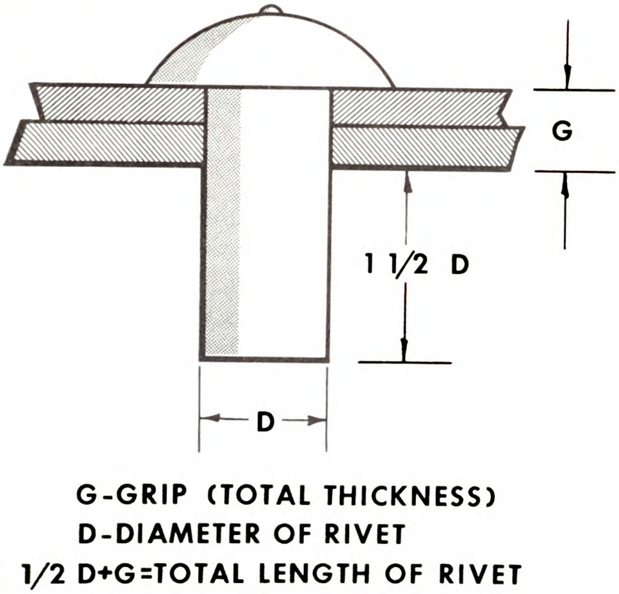

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Figure 10-1.—Rivet length.

Table 10-1.—Guide for selecting rivet size for sheet metal work.

Gage of sheet metal	Rivet size (weight in pounds per 1,000 rivets)
26	1
24	2
22	2 1/2
20	3
18	3 1/2
16	4

There are no specific rules which are applicable to every case or type of riveting. There are, however, certain general rules which should be followed.

Rivet Spacing

Rivet spacing (pitch) depends upon several factors, principally the thickness of the sheet, the diameter of the rivets, and the manner in which the sheet will be stressed. Rivet spacing should never be less than 3D (3 times the rivet diameter). Spacing is seldom less than 4D nor more than 8D.

Transverse Pitch

When two or more rows of rivets are used in a repair job, the rivets are staggered to obtain maximum strength. The distance between the rows of rivets is called transverse pitch. Transverse pitch is usually 75 percent of rivet pitch.

Edge Distance

Edge distance for all rivets, except those with a flush head, should not be less than 2D (twice the diameter of the rivet shank) nor more than 4D. Flushhead rivets require an edge distance of at least 2 1/2D. If rivets are placed too close to the edge of the sheet, the sheet is apt to crack or pull away from the rivets; and if placed too far away from the edge, the sheet is apt to turn up at the edge.

NOTE: On most repairs, the general practice is to use the same rivet spacing and edge distance that the manufacturer used in the surrounding areas. Figure 10-2 illustrates rivet spacing and edge distance.

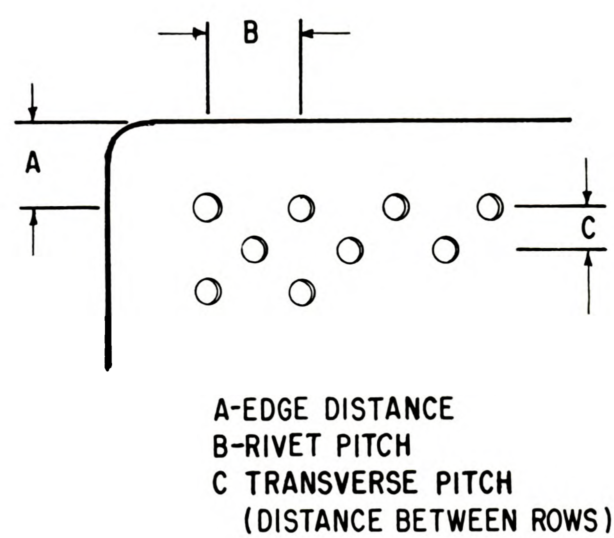

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Figure 10-2.—Rivet spacing and edge distance.

DRILLING RIVET HOLES

Standard twist drills are used for drilling rivet holes. Table 10-2 specifies the size drill for the various size rivets. Note that there is a slight clearance in each case, which prevents binding of the rivet in the hole.

Table 10-2.—Drill sizes for various size rivets.

Rivet diameter	Drill size	Drill size
3/32	No. 41	0.0960
1/8	No. 30	.1285
5/32	No. 21	.1590
3/16	No. 11	.1910
1/4	No. F	.2570
5/16	No. P	.3230
3/8	No. W	.3860

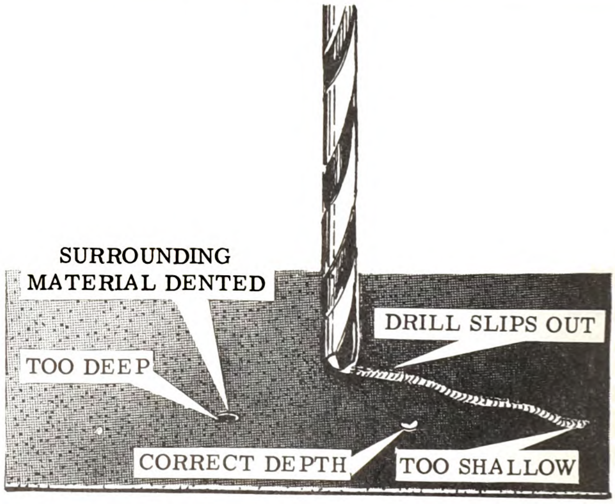

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Figure 10-3.—Drilling holes for rivets.

Locations for the rivet holes should be center punched and the drilling done with a power drill, either electric or pneumatic, having a 1/4-inch capacity chuck. The electric drill must not be used where flammable vapors, gases, liquids, or exposed explosives are present. The center-punch mark should be large enough to prevent the drill from slipping out of position, but must not be made with enough force to dent the surrounding material. (See fig. 10-3.) The drilling can be done with a hand drill if no power drill is available. All burrs must be removed before riveting by using a larger size drill, or by using a deburring tool.

Use of Portable Drills

Before using a drill, turn on the power and check the drill for trueness and vibration. Do not use a drill bit that wobbles or is slightly bent. Trueness may be visibly checked by running the motor freely.

The most common error made by the inexperienced man is to hold a portable drill at an incorrect angle to the work. Make sure the drill is held at a right angle to the work. When drilling in a horizontal position, it can be seen if it is too far to the right or left, but it is difficult to tell if the rear of the drill is too high or too low. Until the ASH learns how to hold a drill at the correct angle, he should have another man sight the angle before starting the drill.

Another common mistake is to put too much pressure on the drill. Pushing or crowding a drill may break the drill point. Also, it will cause the drill to plunge through the opposite side of the sheet, leaving rough edges around the hole.

The drill should not be stopped immediately upon breaking through, but should be inserted for approximately half its length while still running, and then withdrawn. This operation requires judgment and skill since it is very easy to ream the hole oversize; but if this is done properly, cleaner holes will result.

FLUSH RIVETING

In some instances, the ASH is required to use flush rivets in making a repair. These rivets are difficult to install, since the parts being riveted must be countersunk, which is one extra operation following drilling. Another hazard is the closeness of the rivet set to the metal during riveting. If considerable skill is not used, the metal will be damaged by the rivet set. Flush rivets are made with heads of

several different angles, but the 100-degree rivet is the most commonly used type.

The two methods used in countersinking for flush riveting are dimple and machine countersinking. In some instances, a combination of the two may be used; in other words, the top sheet of an assembly may be dimpled while the under sheet is machine countersunk.

Dimple Countersinking

Dimple countersinking is accomplished by using male and female dies (fig. 10-4). The forming of a dimple is a combined bending and stretching operation. A circular bend is formed around the hole. As in any bending operation, the tension force at the upper side of the bend (break) creates the radius at the junction of the two surfaces—the top side of the sheet and the downward-bent inner wall of the dimple depression.

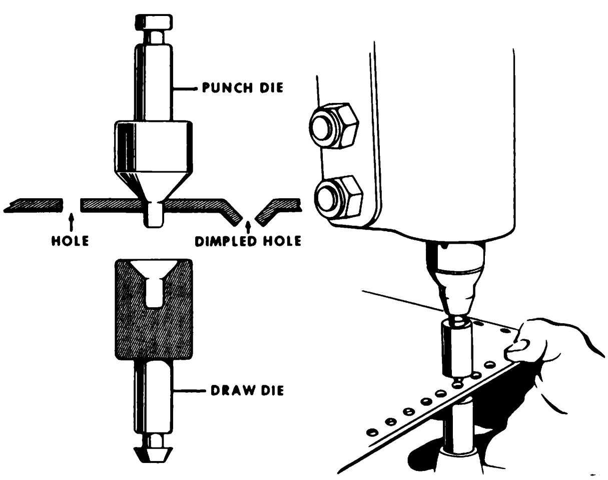

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Figure 10-4.—Dimple countersinking.

The stretch occurs around the hole as it is displaced from its original position and relocated at the bottom of the dimple. The female die must have a slightly larger cone diameter than the corresponding dimension of the male die. This allows for material thickness and relieves the bending load at the break, thus avoiding circumferential cracks around the boundaries of the dimple. As a further safeguard, a slight radius is made on the female die at the junction of the top face with the dimple depression.

Dimpling dies are made to correspond to any size and degree of countersink rivet head available. The dies are numbered, and the correct combination of dies to use is indicated in charts specified by the manufacturer. Both male and female dies are machined accurately and have highly polished surfaces. When dimpling a hole, place the material on the female die and insert the male die in the hole to be dimpled. The dies are generally brought together, forming the dimple by a mechanical or pneumatic force.

As newer alloyed metals were developed to increase the shear and tensile strength, they became increasingly difficult to form, since they are harder and more brittle. These materials are subject to cracking when formed and dimpled cold. For this reason, it is necessary to use a hot dimpling process. The application of hot dimpling to the more brittle materials is advantageous for the reduction of cracking and also from the standpoint of dimple shape. The heat is applied to the material by the dies, which are maintained at a specific temperature by electric heaters. The heat is thus transferred to the material to be dimpled only momentarily and none of the heat-treat characteristics of the material are lost. The manufacturer's manual must be consulted for the operating procedures of hot dimpling equipment.

When setting up any dimpling equipment, follow the step-by-step procedure outlined in the Operating and Maintenance Manual supplied with the equipment. Since equipment types vary, it is impractical to specify a standard procedure in this manual. However, there are four general requirements of a dimple; and by examining each, it is possible to denote improper setting up of the equipment.

1. Sharpness of definition. It is possible to get a dimple with a sharp break from the surface into the dimple. The sharpness of the break is controlled by two things—amount of pressure and material thickness.

2. Condition of dimple. The dimple must be checked for cracks or flaws that might be caused by damaged or dirty dies.

3. Warping of material. The amount of warpage may be held to a minimum if the correct pressure setting is held. When dimpling a strip with too much pressure, the strip tends to form a convex shape as shown in figure 10-5.

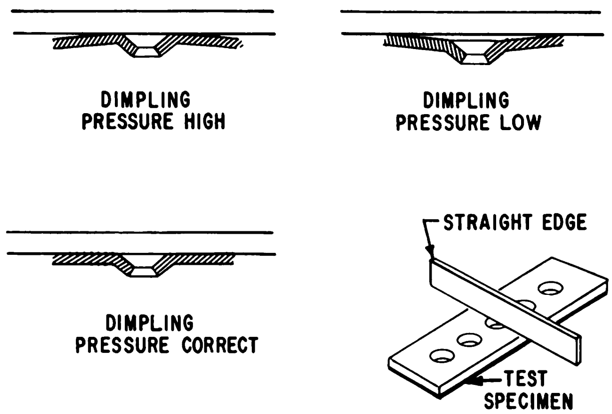

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Figure 10-5.—Checking dimple equipment air pressure.

When insufficient pressure is used, it tends to form a concave shape. This can be checked by using a straightedge.

4. General appearance. The dimple should be checked with the fastener that is to be used, making sure it meets the flushness requirement. This is important, as the wrong size dies are sometimes used by mistake.

Machine Countersinking

Machine countersinking is used for flush-riveting all sheet 0.064 inch and greater in thickness. A countersink has a cutting face beveled to the angle of the rivet head and is kept centered by a pilot shaft inserted in the rivet hole. A stopping device automatically acts as a depth gage so that the hole will not be countersunk too deep. Figure 10-6 shows a stop type countersink.

The countersink should always be equipped with the fiber collar (fig. 10-6) to prevent marring of the metal surface. A hand, electric, or air drill may be used to operate the countersink, and should not be operated above 2,500 rpm. The countersink must be sharp to avoid vibration and chatter. Figure 10-7 illustrates several effects of incorrect countersinking.

RIVET DRIVING PROCEDURES

There are two methods of riveting with which the ASH should be familiar—the hand riveting method and the pneumatic hammer method. The hand riveting procedures are described in Tools and Their Uses, NavPers 10085-B. Therefore, only pneumatic riveting is covered in this manual.

Pneumatic Hammer Riveting

Pneumatic hammer riveting is the most common method for driving rivets. The rivet guns described in chapter 5 are used for this process. The procedure for this method of riveting, which is quite different from the hand riveting method, is discussed in the following paragraphs.

Before driving any rivets, make sure all holes line up perfectly, all shavings and burrs have been removed, and the parts to be riveted are fastened securely together. It is important that the sheets be held firmly together in the immediate area of the rivet being driven.

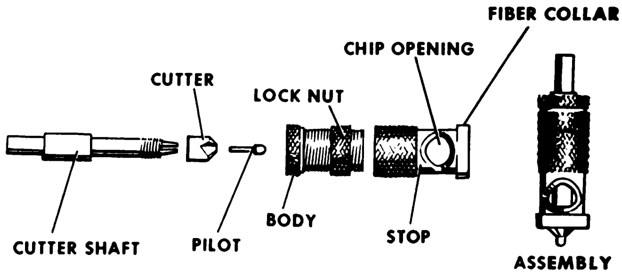

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Figure 10-6.—Stop type countersink.

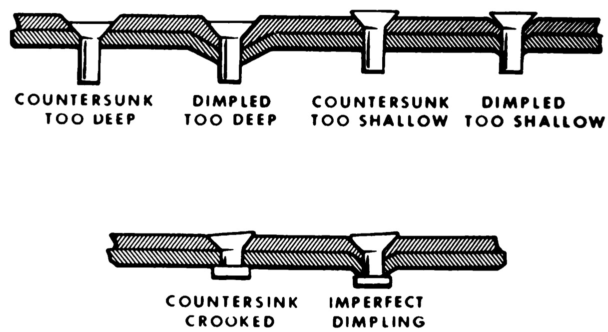

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Figure 10-7.—Incorrect countersinking.

To adjust the speed of the rivet gun, place it against a block of wood. Never operate a rivet gun without resistance against the set, as the vibrating action may cause the retaining spring to break, allowing the set to fly out.

NOTE: Rivet sets used with the pneumatic rivet gun are different from the set used with the hand riveting method. These differences are discussed in chapter 5.

CAUTION: A rivet set can be a deadly weapon. If a rivet set is placed in a rivet gun without a set retainer and the throttle of the gun is opened, the rivet set may be projected like a bullet. This may cause either severe injury to a person or the destruction of equipment.

The gun should be adjusted so that the rivet may be driven in the shortest possible time, but care must be taken not to drive the rivet so hard or in such a manner as to dimple the metal. Practice will enable one to properly adjust a gun for any type of work.

When the rivet has been pushed into the proper position and held there firmly with the set of the rivet gun resting squarely against the rivet head, the bucking bar is held firmly and squarely against the protruding rivet shank. (In most instances, the bucking bar must be manipulated by another man, called the bucker.) The gunner then exerts pressure on the trigger and starts driving. The gun must be held tightly against the rivet head and must not be removed until the trigger has been released.

The bucker removes the bucking bar and checks the upset head after the gunner has stopped driving. A signal system is usually employed to develop the necessary teamwork and consists of tapping lightly against the work. One tap may mean "not fully driven, hit it again"; two taps may mean "good rivet"; three taps may mean "bad rivet, remove and drive another"; etc.

The upset head, often referred to as the bucktail, should be one and one-half times the original diameter of the original shank in width and one-half times the original diameter in height as shown in figure 10-8. If the head thus formed is narrower and higher than the dimensions given, more driving is necessary. If it is wider and shallower, it must be removed and replaced.

RIVET REMOVAL

Rivets must be removed and replaced if they show even the slightest deformity or lack of

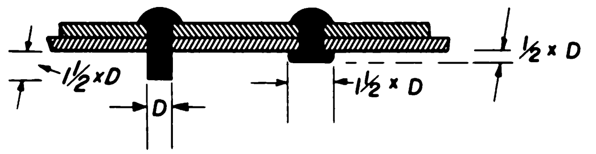

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Figure 10-8.—Rivet dimensions before and after bucking.

alignment. Among the reasons for replacing rivets are the following: Rivet marred by bucking bar or rivet set; rivet driven at slant, or shank bent over; rivet too short, causing head to be shallow; rivet pancaked too flat from overdriving; sheets spread apart and rivet flashed between sheets; rivet driven too lightly, causing sheets to buckle; two rivet heads not in alignment; and head of countersunk rivet not flush with outside surface or driven below the surface. Examples of these incorrectly driven rivets are shown in figure 10-9.

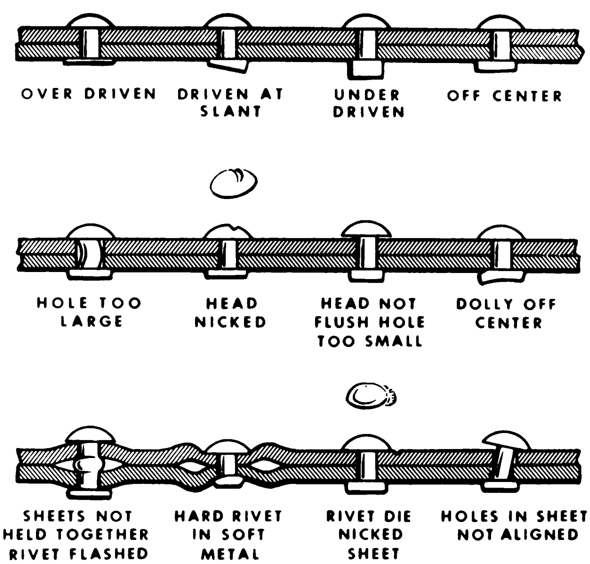

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Figure 10-9.—Incorrectly driven rivets.

When removing rivets, care should be taken not to enlarge the rivet hole, as this would necessitate the use of a larger size rivet for replacement. To remove a rivet, file a flat

surface on the manufactured head if accessible. It is always preferable to work on the manufactured head rather than on the one that is bucked, since the former will always be more symmetrical about the shank.

Indent the center of the filed surface with a center punch and use a drill of slightly less than shank diameter to drill through the rivet head. Remove the drill and, with the other rivet end supported, shear the head off with a sharp chisel. Always cut along the direction of the plate edge. If the shank is unduly tight after the removal of the head, the shank should be drilled out. However, if the sheet is firmly supported from the opposite side, the shank may be punched out with a drift punch. (See fig. 10-10.)

The removal of flush rivets requires slightly more skill. If the formed head on the interior is accessible and has been formed over heavy material such as an extruded member, the formed head can be drilled through and sheared off, as mentioned previously. If the material is thin, it may be necessary to drill completely through the shank of the rivet and then cut the formed head with diagonal cutting pliers. The remainder of the rivet may then be drifted out from the inside.

BLIND RIVET INSTALLATION

As stated in chapter 5, the most common types of blind rivets—self-plugging (friction lock), self-plugging (mechanical lock), and Rivnut—are described and illustrated in Airman, NavPers 10307 (Series). The special tools required and the installation and removal methods for these types of rivets are covered in the following sections. Selection of the proper equipment depends on a number of variables—space available for equipment, type of rivets to be driven, availability of air pressure, etc.

Installation Tools for Friction Lock Rivets

The guns used for installing this type of self-plugging rivet are the G-11 hand gun and

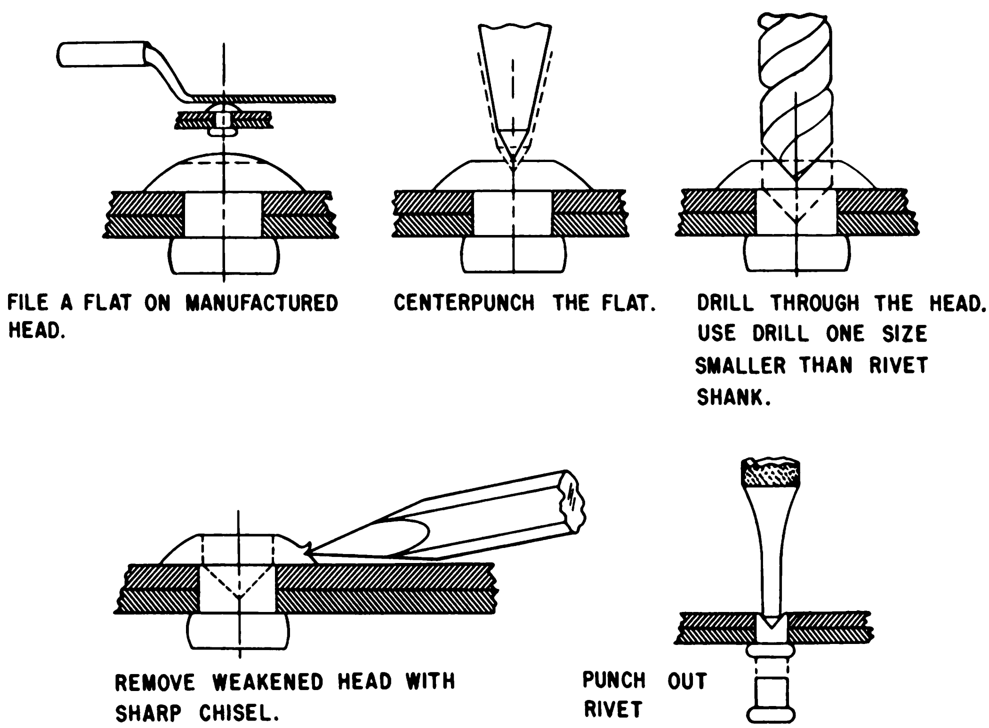

Figure 10-10.—Removal of rivets.

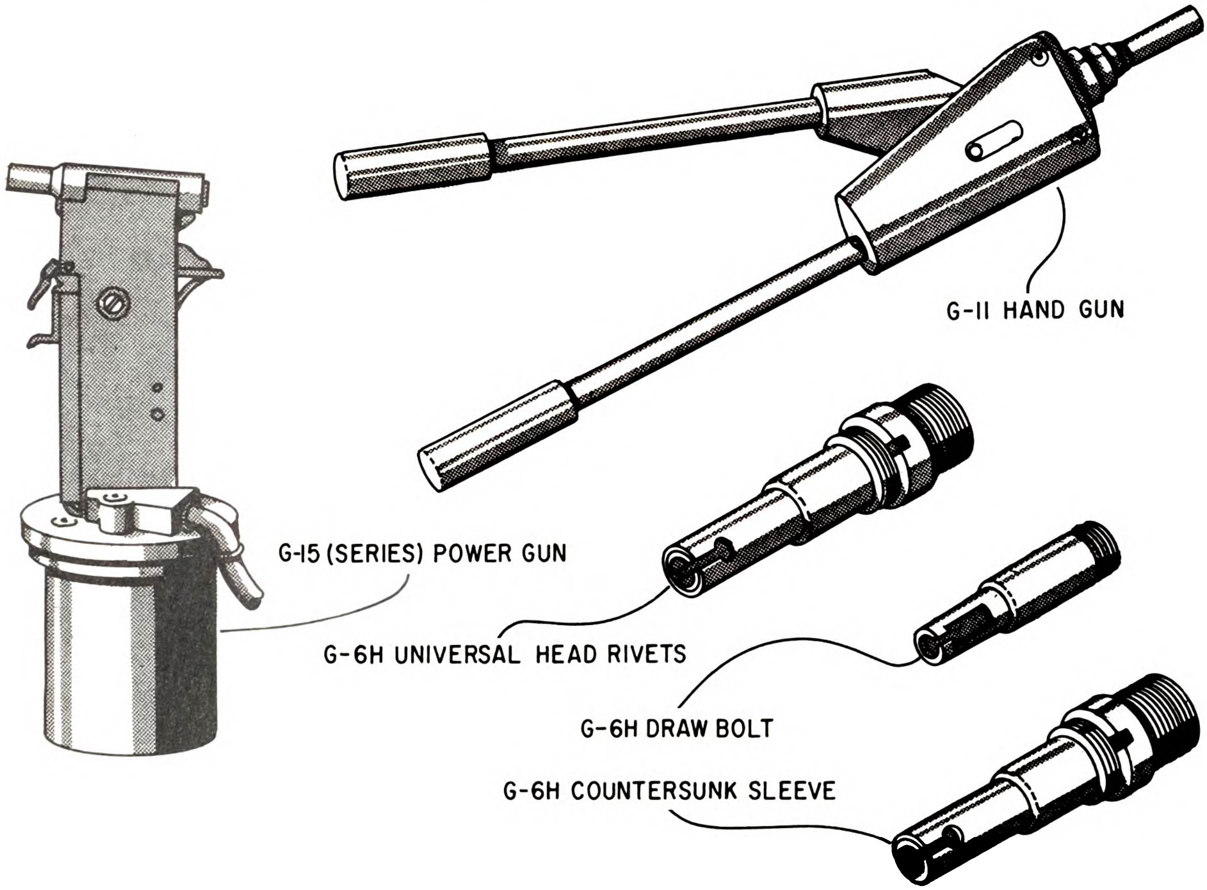

Figure 10-11.—Self-plugging rivet (friction lock) installation tools.

the G-15 (series) and G-40 (series) power guns. The G-15 power gun uses G-6H pulling heads as does the G-11 hand gun. The G-40 power gun uses the H-40 pulling heads primarily; however, through the use of a 226 adapter, G-6H heads may be used. Extensions are available for all guns using G-6H heads. Figure 10-11 shows the G-11 and G-15 rivet guns with the G-6H pulling heads.

The heads are manufactured in three different sizes to accommodate the different rivet diameters. For ease of selection, the sizes are stamped on the parts of the pulling heads.

Installation Procedures

It is important that the proper drawbolt and sleeve be used for the rivet being installed. The drawbolt should correspond to the diameter of the rivet, and the sleeve should correspond to the rivet diameter and head style. Speed of installation may be increased by inserting a number of rivets in the work and then applying the gun. In other instances, such as overhead work, it is apparent that this method would be impractical and the rivet should be loaded into the gun and then inserted into the prepared hole. The rivet must be completely inserted into the slot in the drawbolt, because improper seating of the rivet may permit the head to break off before the rivet is completely set. (See fig. 10-12.)

When using a hand gun, hold the rigid handle of the gun parallel to the rivet axis. Open the movable handle as far as it will go, then

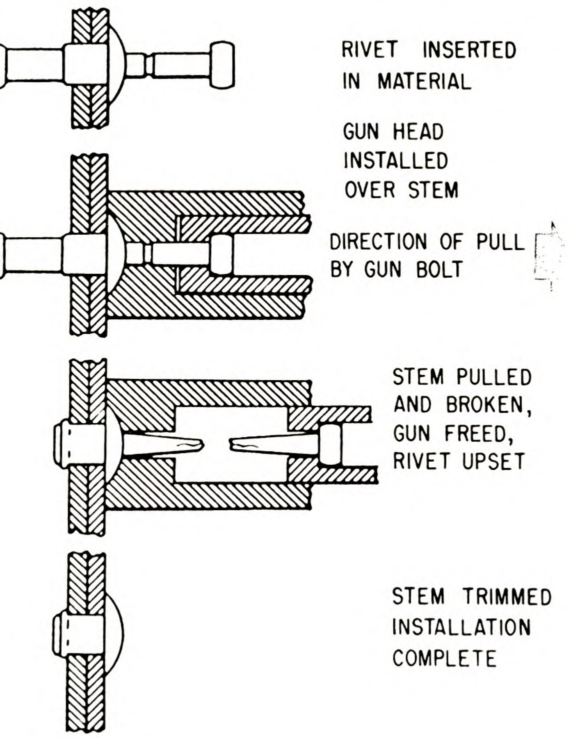

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Figure 10-12.—Self-plugging rivet (friction lock) installation.

rtially close. Repeat this operation until the vet stem breaks, then release the gun by mpletely closing the movable handle.

When using the power gun, hold the head of e gun parallel to the axis of the rivet. Push e gun against the work with enough force to at the head of the rivet firmly, and to insure ntact between the parts being riveted. Pull e trigger until the stem breaks. The stem ll be ejected through the rubber tube at the ck of the gun head. It is important that this be be in place in order to prevent stems from tting into the gun mechanisms.

spection

The rivet is satisfactory if the pin is firm d the head is seated tightly on the face of the aterial. Occasionally, the head will rise ghtly in the area which was under the slot of e pulling head. This condition is acceptable the head is not too badly deformed and the tension characteristics of the joint are not made critical by the deformation of the head. Figure 10-13 illustrates satisfactory and unsatisfactory self-plugging rivets.

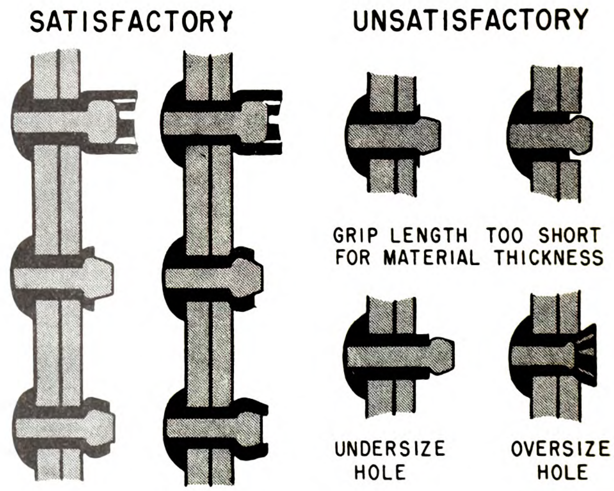

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Figure 10-13.—Inspection of self-plugging rivets (friction lock).

Removal

These rivets are removed in much the same manner as the common, solid shank rivets, except for the preliminary step of driving out the rivet stem. (See fig. 10-14.)

1. Punch out the rivet stem with a pin punch.
2. Drill out the rivet head, using a drill slightly smaller than the rivet shank.
3. Pry off the weakened rivet with a pin punch.
4. Push out the remainder of the rivet shank with a pin punch. If the shank will not push out, drill the shank, taking care not to enlarge the hole in the material. If the hole should be enlarged, finish-drill for an oversize rivet.

Installation Tools for Mechanical Lock Rivets

The tool used for driving these rivets is the CP350 blind rivet pull tool. (See fig. 10-15.) The nose of the tool includes a set of chuck jaws which fit the pull grooves in the rivet pin, and pull the pin through the rivet shank to drive

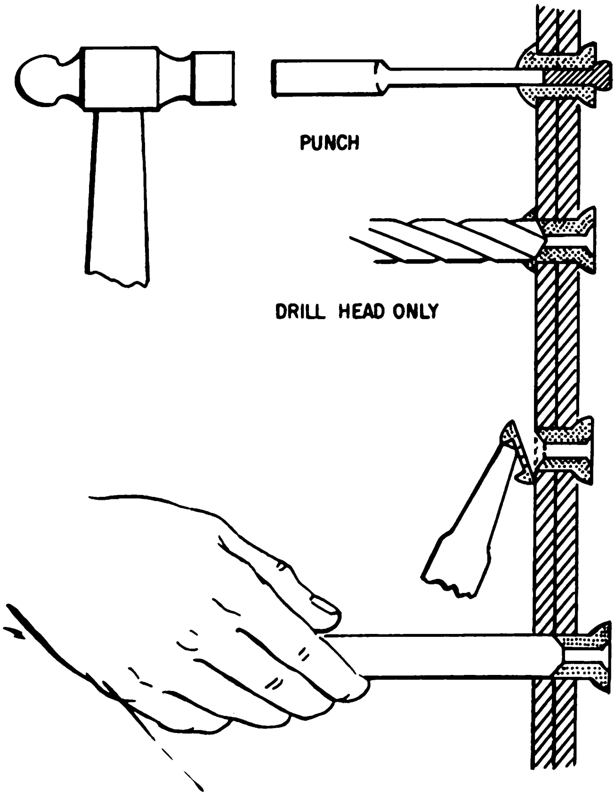

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Figure 10-14.—Removal of self-plugging rivets (friction lock).

the rivet; an outer anvil which bears against the outer part of the manufactured head during the driving operation; and an inner anvil which advances automatically to drive the locking collar home after the blind head is formed. A short nose assembly, interchangeable with the standard assembly, is available for use in areas where there is not sufficient clearance for the standard nose.

A change in rivet diameter requires a change in chuck jaws, outer anvil, inner anvil, inner anvil thrust bearing, and an adjustment of the shift valve operation pressure as described below. A change in the rivet head type from brazier head to countersunk head, or vice versa, requires a change of outer anvil only, if there is no change in the rivet diameter.

A special chuck jaws assembly tool is furnished with the tool. To facilitate insertion of the chuck jaws into the chuck sleeve, mount the three jaws on this assembly to form a cone, and lower the inverted chuck sleeve over the jaws.

Always be sure that the pull tool is equipped with the correct size chuck jaws, outer and inner anvils to fit the rivets being driven, and that the relief valve operation pressure is properly adjusted for the size rivets being driven. Also make sure that the rivets being driven are of proper length. The tool has only one operating adjustment. This adjustment is used to control the pull on the pin at which the inner anvil advances. The desired amount of the pull depends on the diameter of the rivets to be installed, and the pull is varied by changing the pressure at which the adjustable shift valve operates. To adjust, proceed as follows:

1. Remove pipe plug from tool cylinder and connect a pressure gage to the tool.

2. Press trigger and release it the instant a pull of exhaust indicates that the shift valve controlling the inner anvil has shifted. The gage will then indicate the shift pressure. See table 10-3 for the approximate pressures.

Table 10-3.—Adjustments for CP350 blind rivet pull tool.

Rivet diameter	Shift valve operating pressure
1/8	30 to 31 psi
5/32	46 to 47 psi
3/16	66 to 67 psi

NOTE: The trigger must be released immediately as the valve shifts. Otherwise the gage will record the higher pressure which builds up as soon as the valve has shifted.

3. To adjust the pressure, loosen the valve-adjusting screw locknut and turn the valve-adjusting screw clockwise to increase pressure, or counterclockwise to decrease pressure, until the desired pressure is obtained. Check the pressure after tightening the valve-adjusting screw locknut. When rivets of extremely long grip length are to be driven, an adjustment to the high-pressure limit should be made. For efficient operation of the tool, the minimum desired line pressure should be not less than 90 psi and the maximum not more than approximately 110 psi.

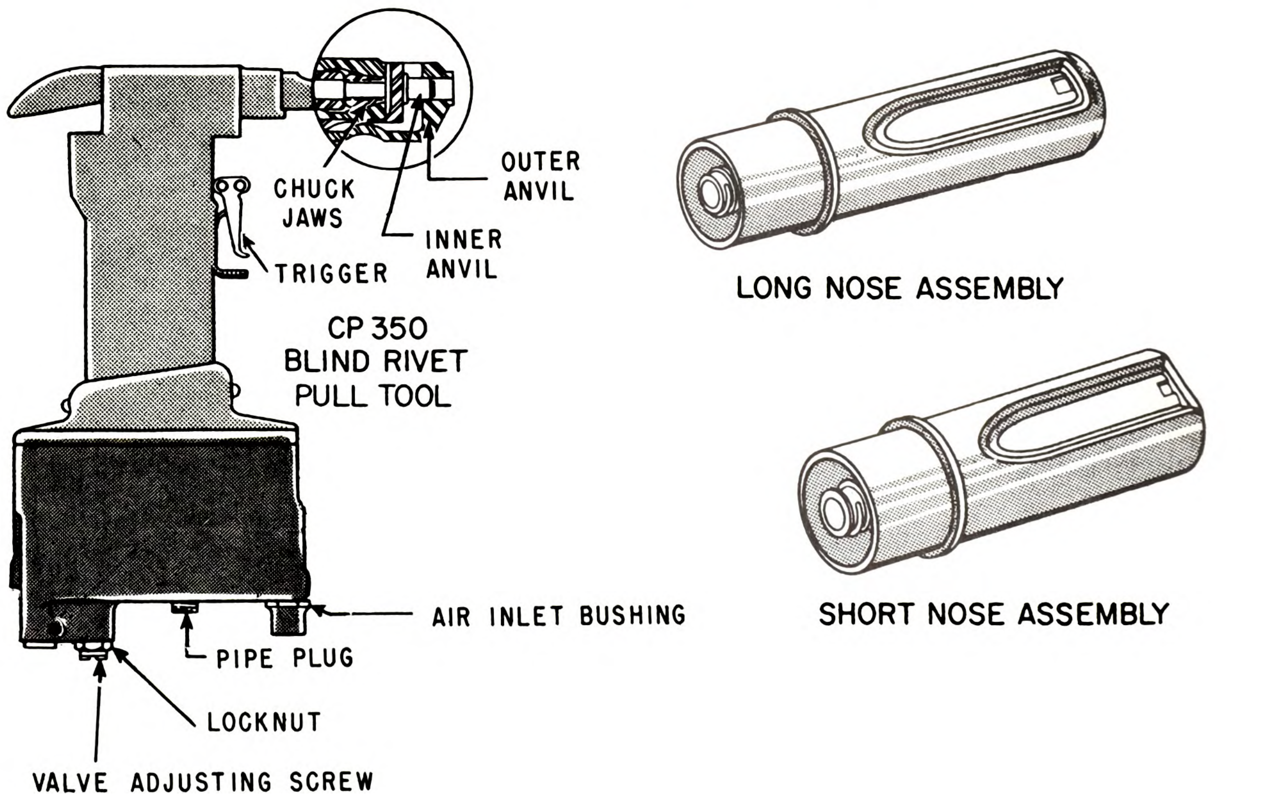


Figure 10-15.—Self-plugging rivet (mechanical lock) pull tool.

Installation Procedures

Proper driving procedures are vital to obtain a firm joint. The recommended procedures are as follows:

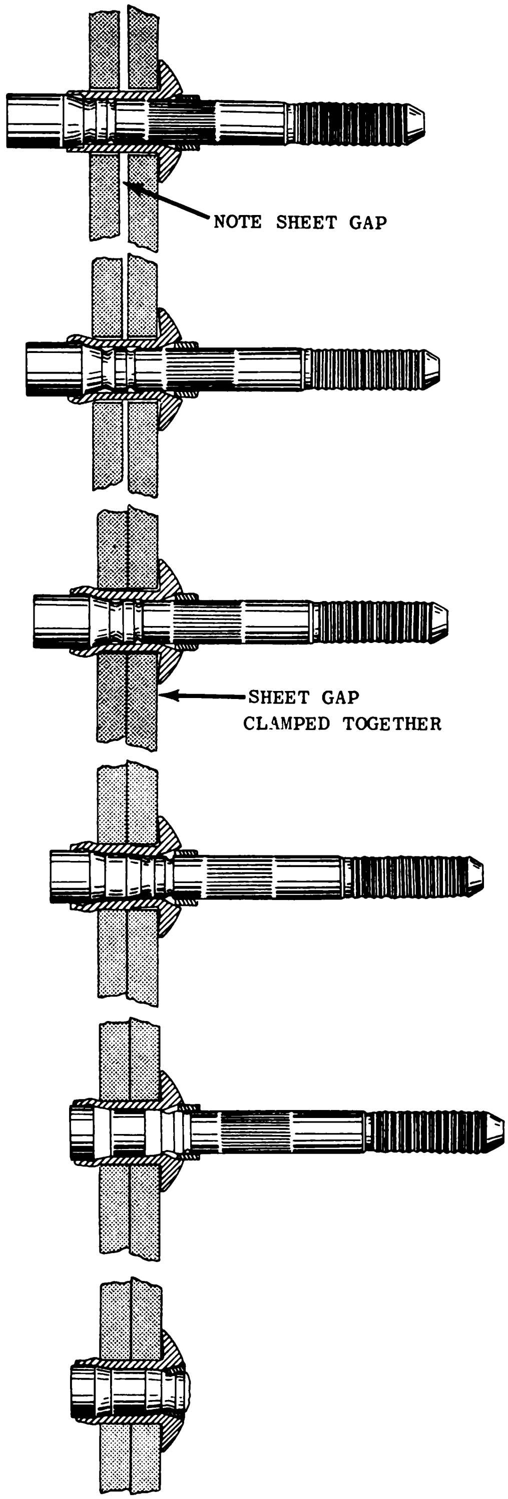
1. Hold the head of the gun steady and at a right angle to the work.
2. Press on the head of the gun hard enough to hold the rivet firmly against the work. Do not use a great amount of pressure unless necessary.
3. Squeeze the gun trigger and hold until the rivet pin breaks, then release the trigger. The next rivet should not be driven until the return action has caused the gun to latch. A distinct click will be heard, indicating that the gun is ready for the next installation cycle.

The rivet is actually cold-squeezed by the action of the pin head drawing against the hollow shank end. Shank expansion through the action of the extruding angle, blind head formation, and setting of the mechanical lock in the rivet head all follow in automatic sequence and require but a fraction of a second. Figure 10-16 shows in sequence the steps in driving the mechanical lock self-plugging rivet.

Inspection

Visual inspection of the seating of the pin in the manufactured head is the most reliable and simple means of inspection. (See fig. 10-16.)

If the proper grip length has been used and the locking collar and broken end of the pin are approximately flush with the manufactured head, the rivet has been properly upset and the lock formed. Insufficient grip length would be indicated by the pin breaking below the surface of the manufactured head, and excessive grip length would be indicated by the pin breaking off well above the manufactured head. In either case, the locking collar might not be properly seated, thus forming an unsatisfactory lock.



(1) Mechanical-lock rivet before installation. Note shorter stem on blind side providing marked improvement for limited blind clearance applications.

(2) As the stem is pulled into the rivet sleeve, it immediately forms the blind head. The mechanical-lock always forms the blind head firmly against the blind sheet.

(3) Continued movement of the stem pushes the blind sheet ahead of the blind head until the sheets are firmly clamped together and the rivet is firmly seated.

(4) The plugging portion of the stem expands the rivet sleeve to fill the hole and reduces in diameter as it passes through the rivet sleeve, providing excellent hole fill —even in oversize holes.

(5) The movement of the stem is stopped by the pulling head at a point where the groove in the stem and the chamfer in the rivet line up to make a receptacle for the locking ring.

(6) The pulling head shifts automatically, inserts the positive mechanical locking ring, and fractures the stem flush with the rivet head.

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Figure 10-16.—Self-plugging rivet (mechanical lock).

Removal

Removal of this rivet (fig. 10-17) is accomplished easily without damage to the work by use of the following procedure:

1. Shear the lock by driving out the pin, using a tapered steel drift pin not over 3/32-inch diameter at the small end. If working on thin material, back up the material while driving out the pin. If inaccessibility prohibits this, partially remove the rivet head by filing, or remove with a rivet shaver. An alternative would be to file the pin flat, center punch the flat, and carefully drill out the tapered part of the pin forming the lock.

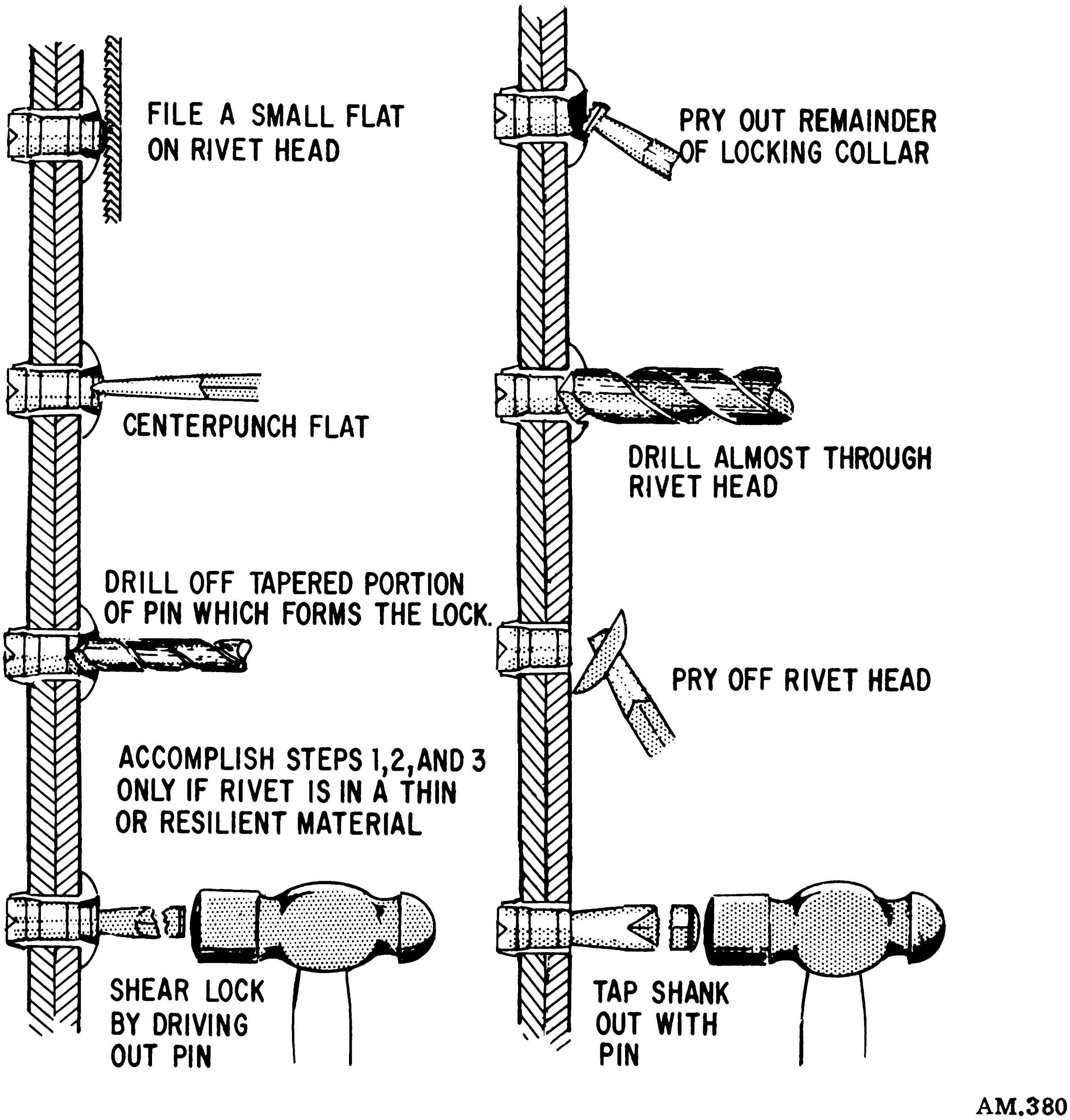

Figure 10-17.—Removing self-plugging rivets.

2. Pry the remainder of the locking collar out with a drift pin.

3. Use the proper size drill to drill nearly through the rivet head. For a 1/8-inch diameter rivet, use a number 31 drill; for a 5/32, use a number 24; and for a 3/16, use a number 15.

4. Break off the drilled head, using a drift pin as a pry.

5. Drive out the remainder of the rivet with a pin having a diameter equal to, or slightly less than, the diameter of the rivet.

Installation Tools for Rivnuts

Tools used in the installation of Rivnuts include the heading tool and the keyway cutter. The heading tool, as shown in figure 10-18, has a threaded mandrel onto which the Rivnut is threaded until the head of the Rivnut is against the anvil of the heading tool. The heading tool comes in sizes 6-32, 8-32, and 10-32 which correspond with the thread sizes of the standard Rivnuts. They are identical, except for the size of their threaded mandrel.

The keyway cutter is used for cutting a notch in the Rivnut hole for the Rivnut keyway. In some instances the keyway cutter cannot be used because the material is too thick. If such is the case, use a small round file to form the keyway.

Installation Procedures

The drilling of holes for Rivnuts requires the same precision as that required for solid shank rivets. The shank of the Rivnut must fit snugly in the hole. To obtain the best results for a flathead installation, first drill a pilot hole smaller than the shank diameter of the Rivnut, then ream to the correct size. Pilot and ream drill sizes for Rivnuts are given in table 10-4.

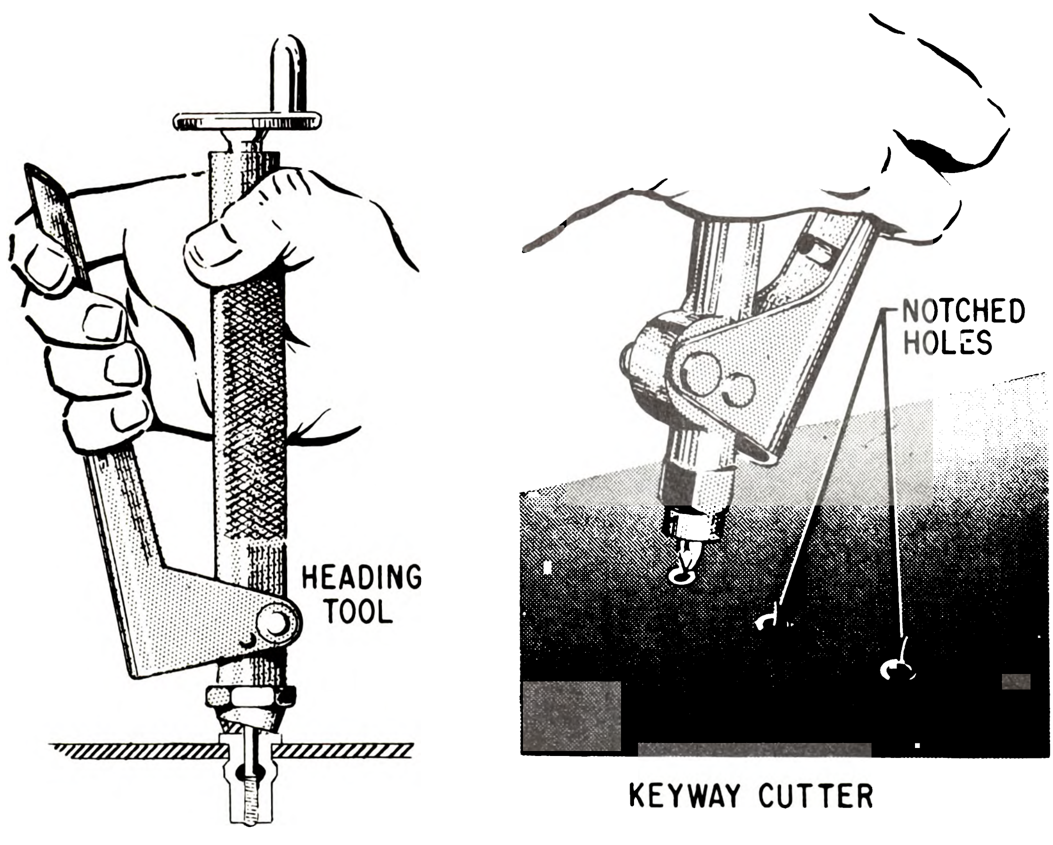

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Figure 10-18.—Hand-operated Rivnut heading and keyway cutter tools.

Table 10-4.—Drill sizes for Rivnuts.

'nut size	6-32	8-32	10-32
ot drill size	19 (0.166)	8 (0.199)	1 (0.228)
am drill size	12 (0.189)	2 (0.221)	1/4 (0.250)

The application of flush Rivnuts is subject to :tain limitations. For metal which has a ckness greater than the minimum grip length the first Rivnut in a series, use the machine intersink; and for metal thinner than the ximum grip length of the first Rivnut in a ries, use the dimpling process.

The countersunk Rivnut should not be used less the metal is thick enough for machine intersinking, or unless the underside is cessible for the dimpling process. Aside om the countersinking operation, the proce- re for installing a flush Rivnut is the same that for the flathead Rivnut.

When installing Rivnuts, always check the readed mandrel of the heading tool to see that is free from burrs and chips from the previ- s installation. Then screw the Rivnut onto mandrel until the head touches the anvil. sert the Rivnut in the hole (with the key posi- ned in the keyway, if a key is used) and lding the heading tool at a right angle to the rk. Press the head of the Rivnut tightly ainst the sheet while slowly squeezing the ndles of the heading tool together until the vnut starts to head over. Then release the ndle and screw the stud farther into the vnut. This prevents stripping the threads of Rivnut before it is properly headed. Again ueeze the handles together until the Rivnut ading is complete. Now remove the stud of heading tool from the Rivnut by turning the ank counterclockwise.

The action of the heading tool draws the vnut against the anvil, causing a bulge to m in the counterbored portion of the Rivnut the inaccessible side of the work. This lge is comparable to the upset head on an dinary solid shank rivet. The amount of ueeze required to head the Rivnut properly is st determined by practice.

When keyed Rivnuts are used, cut the keyway after the hole has been reamed. Operate the keyway cutter by inserting it in the hole and squeezing the handles. Always cut the keyway on the side of the hole away from the edge of the sheet.

Inspection

After the installation of Rivnuts, as well as other fasteners, the ASH must inspect the complete installations. The Rivnuts are inspected for the following: Manufactured head is inspected for correct installation of the Rivnut keyway in its keyway slot, insuring it is flush with the surface in which it is installed. The threaded portion of the Rivnut shank is inspected for cracks, stripped threads, and general condition. Threads that are found to be stripped may have an improperly upset head. The stripped threads would also prevent the installation of screws.

NOTE: Rivnuts which are not to be used at the time of installation, or not used for any other reason, should be plugged with a screw designed specifically for that purpose. This will eliminate pockets, which could hold moisture and cause corrosion if left open.

Removal

Defective Rivnuts should be replaced by the same size Rivnuts whenever possible. When the hole has been enlarged by removal, substitution of the next larger size can be made. To remove a Rivnut, select a drill the same size as the original hole. Drill out the Rivnut head, using light pressure and the hollow Rivnut shank as a guide. The Rivnut shank should fall out of the hole behind the sheet, or it may be drifted out, using a pin punch.

SHEET METAL REPAIR

Most of the sheet metal repair required of the ASH consists of the fabrication and installation of patches. Sheet metal repair patches may be divided into two general types—the LAP PATCH and the FLUSH PATCH. A lap patch is an external patch that has the edges of the patch and the existing sheet metal surface overlapping each other. The overlapping portion of the patch is riveted to the existing sheet metal.

A flush patch consists of a filler patch which is flush with the existing surface when inserted.

It is backed up and riveted to a reinforcement plate which, in turn, is riveted to the inside surface of the existing sheet metal. This reinforcement plate is usually referred to as a doubler or backup plate.

The installation of lap and flush patches is described in the following sections.

LAP PATCHES

Lap patches may be installed in areas where smoothness and appearance are not important. In areas where it is permitted, the lap patch may be used in repairing cracks as well as small holes.

In repairing cracks, always drill a small hole (normally called stop drilling) in each end of the crack before applying the patch. This is normally done by using a No. 30 or a No. 40 drill bit. This prevents the concentration of stress at the apex of the crack and distributes the stresses around the circumference of the hole. The patch must be large enough to install the required number of rivets as determined from the rivet schedule indicated for the gage material in the area which is damaged. (See fig. 10-19.) The recommended patch may be cut circular, square, rectangular, or diamond shape. The edges are normally chamfered (beveled) to an angle of 45 degrees.

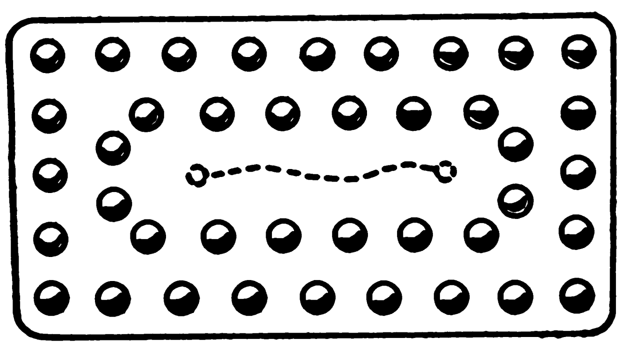

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Figure 10-19.—Lap patch for repairing a crack in sheet metal.

The rivet pattern is laid out on the patch, using the proper edge distance and spacing. The installation position of each rivet is marked with a center punch. The impress in the material made with the center punch helps to keep the drill from slipping away from the hole being drilled. (See fig. 10-3.) Drill only a minimum number of rivet holes in the patch; normally, four will suffice at a distance of 90 degrees from each other. Position the patch over the surface being repaired, insuring that the correct edge distances are being maintained.

Drill four holes in the surface being repaired, using the predrilled holes in the patch as a pattern for alignment. As each hole is drilled, using the proper temporary fasteners, secure the patch in place. When the patch is temporarily secured, drill the remaining rivet holes through the patch and surface being prepared. Remove the patch and deburr all the rivet holes, using a deburring tool or a large drill bit. Prime the repair materials with the proper corrosion preventive material prior to the riveting operation. Secure the patch in position, using temporary fasteners to maintain alignment during riveting.

Holes in sheet metal which are less than 3/16 inch in diameter may be repaired by filling with a rivet. Drill the hole and install the proper size rivet to fill the hole. For holes larger than 3/16 inch, the damaged area is removed by cutting and trimming the hole to a circular, square, rectangular, or diamond shape. The corners of the hole should be rounded to a minimum of 1/4-inch radius. The lap patch is fabricated and installed in the same manner as previously explained for repairing cracks.

FLUSH PATCHES

Flush patches should be used when smoothness of the surface area is required. For example, the exterior surfaces of the pod enclosures for airborne (designed to be transported on the external bomb racks of aircraft) gas turbine compressors (GTC's) must be aerodynamically smooth. Therefore, flush patches should be used to repair damages to the exterior surfaces of these pod enclosures.

The type of flush patch used depends on the location of the damaged area. One type is clear of internal structures, and the other is not. These two types of flush patches are described in the following paragraphs.

Nomenclature for Figure 10-20

1) Assumed damage.
2) Damage cut out to a smooth round hole.
3) Doubler split for insertion through cutout.
4) Filler.
5) Doubler riveted in place.
6) Filler riveted in place.

'lush Patch Clear of
nternal Structures

In areas which are clear of internal struc-
ures, the repair is relatively simple to make.
'his is especially true where there is an ac-
ess door or plate through which the rivets can
e bucked. In inaccessible areas, the flush
atch may be made by substituting blind rivets
nd devising a means of inserting the doubler
hrough the opening.

One method is shown in figure 10-20, in
'hich the doubler has been split. To insert the
oubler, slip the split edge under the metal
urface and twist the doubler until it slides in
lace under the surface. The screw in the
enter of the doubler is temporarily installed
o serve as a "handle" for inserting the doubler
hrough the hole. This type patch is normally
ecommended for holes up to 1 1/2 inches in
iameter. It is generally more satisfactory to
rim a hole larger than 1 1/2 inches to a rec-
angular or elliptical shape, rounding all cor-
ers to a generous radius. (See fig. 10-21.)

On larger repair areas it is usually possible
o buck the doubler rivets by inserting and hold-
ng the bucking bar through the center of the
oubler. The filler is then riveted in place
sing blind fasteners if in a closed area. When
lind rivets are used as substitutes for solid
ivets, the next larger size should usually be
sed. The proper edge distance for the substi-
ute fasteners must be maintained.

In all flush patches, the filler should be of
he same gage and material as the original
netal surface. The doubler, generally, should
e of the same material and one gage heavier
han the filler.

When laying out the size of the doubler, the
ength should exceed the width. This enables
he doubler to be slipped in through the hole,
o it can be positioned for installation. This
liminates the splitting and manipulation of the
atch required in installing doublers of square
nd round flush patch repairs.

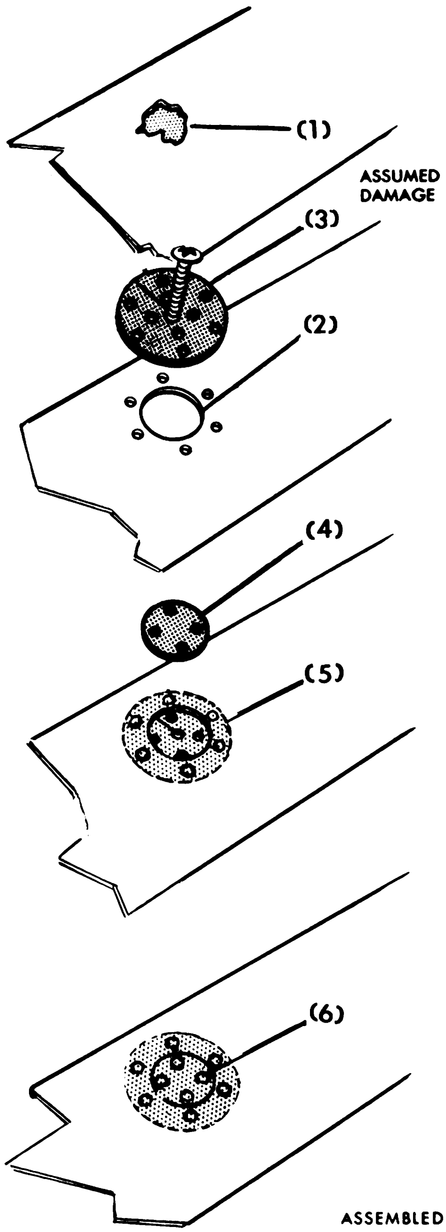

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Figure 10-20.—Repair of small holes in sheet metal surface with a flush patch.

The filler is fabricated slightly less than the dimensions of the hole being repaired. Generally, the maximum clearance between the existing metal and the filler is 1/32 inch. The

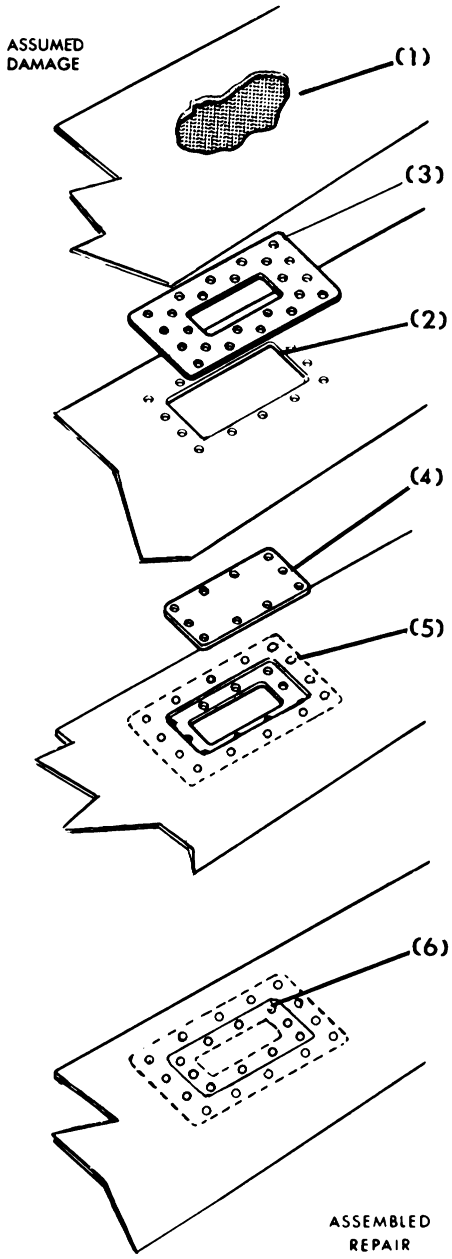

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Figure 10-21.—Flush rectangular patch.

doubler is fabricated larger than the hole being repaired to allow for the specified number of rivets required to attach the doubler to the surface being repaired. The doubler, filler, and attaching surface rivet pattern may be laid

Nomenclature for Figure 10-21

(1) Assumed damage.
(2) Damage cut out to smooth rectangular shape.
(3) Doubler.
(4) Filler.
(5) Doubler riveted in place.
(6) Filler riveted in place.

out, drilled, and deburred in the identical manner as described previously for a lap patch.

After the required corrosion preventive materials have been applied, the doubler is positioned in the structure's interior and secured with temporary fasteners. Inspect the rivet holes for proper alignment. The filler can then be riveted in place using blind fasteners.

NOTE: If the flush repair is accessible from both sides, the filler may be riveted to the doubler prior to installing the doubler.

Flush Patch Over Internal Structures

Fabricating a flush patch over internal structure may tend to become difficult. In some instances, it may be done by simply using a split doubler and a filler, as shown in figure 10-22. Frequently a split doubler, filler strips, and a filler are used in the repair. The filler strip is used as a spacer, if a structural component under the surface has been damaged. In all cases, the existing structural rivet holes should be used when the rivet pattern is laid out. The flush patch over internal structure is installed using the same methods as described for a flush patch clear of internal structure, except for modification of the doubler.

TURNLOCK FASTENER REPAIR

Information concerning the types and uses of turnlock fasteners, including a description of the Airloc fastener, is presented in chapter 5. The Camloc and Dzus fasteners are described in Airman, NavPers 10307 (Series). The repair and installation of these three types of turnlock fasteners are described in the following paragraphs.

CAMLOC INSTALLATION TOOLS

The following list of Camloc tools should be available to assure satisfactory Camloc

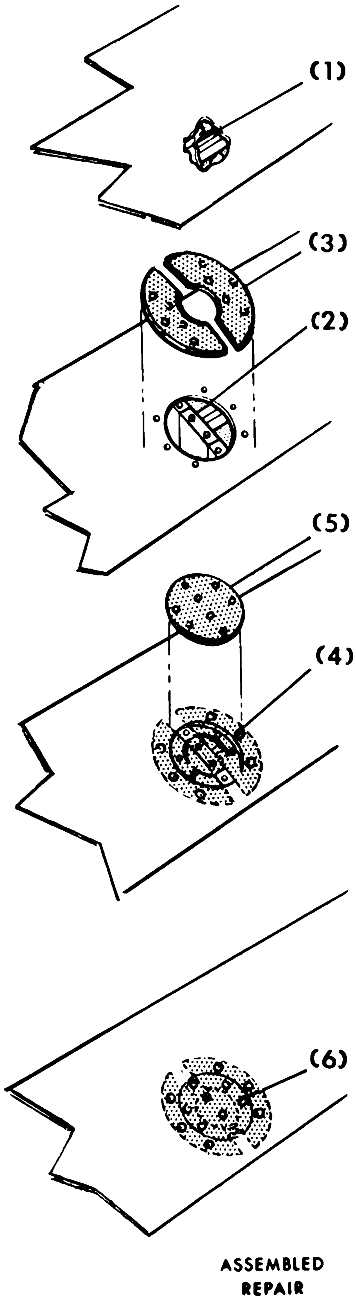

Figure 10-22.—Flush patch over internal structure.

installation, but does not represent the minimum tools required for any particular installation:

Nomenclature for Figure 10-22

(1) Assumed damage.
(2) Damaged metal cut out to a smooth round hole and internal structure repaired.
(3) Two half-round doublers.
(4) Doublers riveted in place.
(5) Filler.
(6) Filler riveted in place.

Pliers, No. 4P3.
Snapring tool, No. T26.
Cutters, Nos. 4-G2C and 4-GC.
Hole saws, Nos. HS-471D and HS-500.
Flaring tools, Nos. T-55-1 and T-50-1.
Dimpling tools, Nos. 4-G200M, 4-G200F, 2-S200M, and 2-S200F.

CAMLOC REPAIR PROCEDURE

Repair of Camloc fasteners includes removal of the damaged stud, grommet, or receptacle; proper preparation of the hole; and installation of the replacement part. In all cases, alignment of the stud, grommet, and receptacle must be maintained. When structural repair of the access door or access frame is necessary, all repair work should be completed before aligning receptacle holes with stud or grommet holes.

Hole preparation is dependent upon the series of fasteners specified and the sheet thickness of the material to which the fastener must be attached. All holes—plain, dimpled, countersunk, or counterbored—should be predrilled undersize.

Remove all chips and burrs before installing the fastener parts. Select the proper size stud, grommet, and/or receptacle. In cases of varying sheet thickness which would cause high locking torque, the stud assembly should be replaced with one of suitable length to increase uniform low locking torque. Stud length increments of 0.030 inch allow for varying material thickness. The total grip length for the stud assembly includes both top and bottom sheet thicknesses.

Grommet selection is determined as follows:

1. In the 4002 series, the grommet is used in combination with the stud assembly, but is dependent upon the type of hole required, the total thickness of the material, and the specified counterbore of the spring.

2. In the 2700 series, the spring cup of the stud assembly eliminates the use of the grommet.

NOTE: Lateral movement of the grommet must be held to a minimum. Vertical movement of the grommet, when the fastener is unlocked, should be held to a minimum to prevent possible loss or fallout of the grommet.

The following repair methods apply to the 4002 series Camloc fasteners.

Stud Damage

Stud assemblies 4002-1 through -15 are removed by compressing the spring with Camloc pliers and lifting out the stud. To install a new stud, compress the spring and insert the stud into the grommet. (See fig. 10-23.) When the spring is released, the stud assembly cannot fall out.

Stud assemblies -16 and longer are retained in the grommet by a split washer. No pliers are required for removal or installation of these studs. The stud is inserted in the grommet, and the split washer is placed on the stud shank between the cross pin and the spring cup. The stud cross pin should not be removed under any circumstances.

Grommet Damage

Remove the grommet by first prying off the snapring and slip the grommet out of the hole. Check for possible damage to the hole size, the

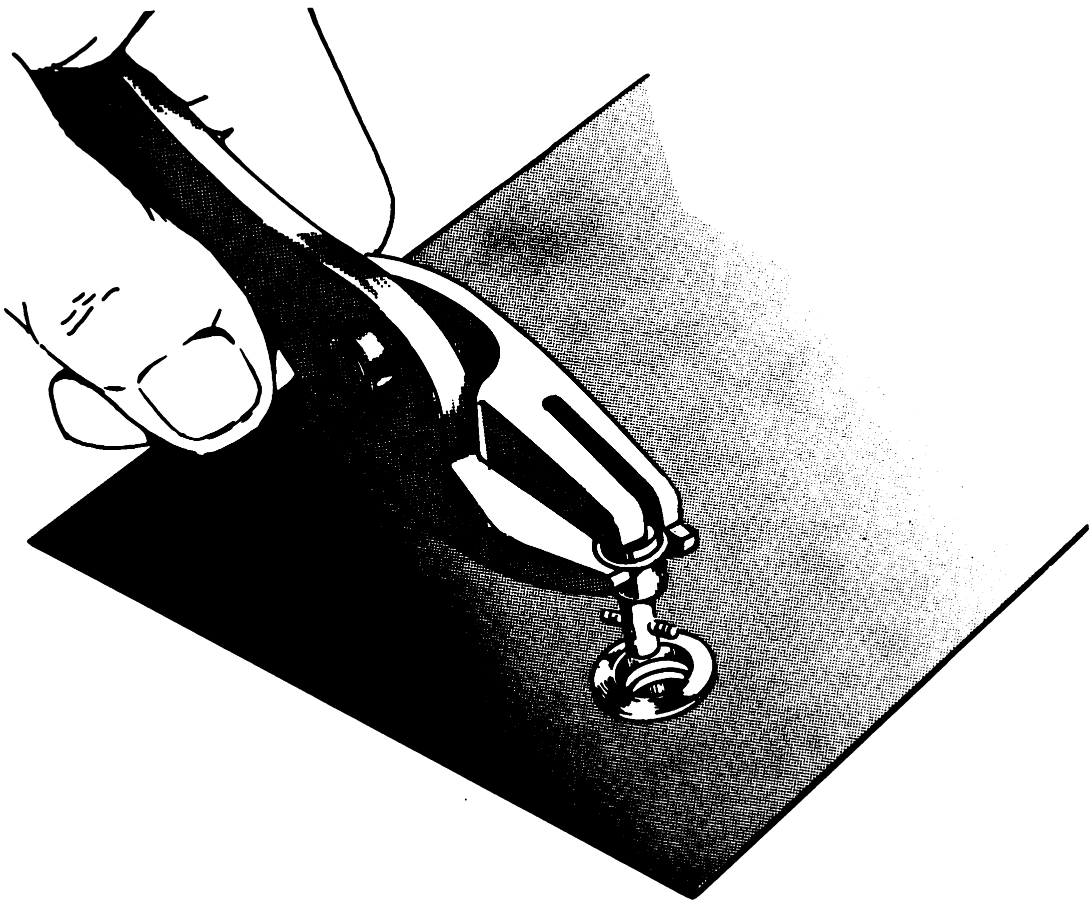

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Figure 10-23.—Installing Camloc stud.

dimple, or countersink, and for correct dimensions. Remove all burrs and install a new grommet identical to the original. Install a new snapring, using the snapring tool T26, as shown in figure 10-24. The snapring must be fully seated behind the shoulder of the grommet.

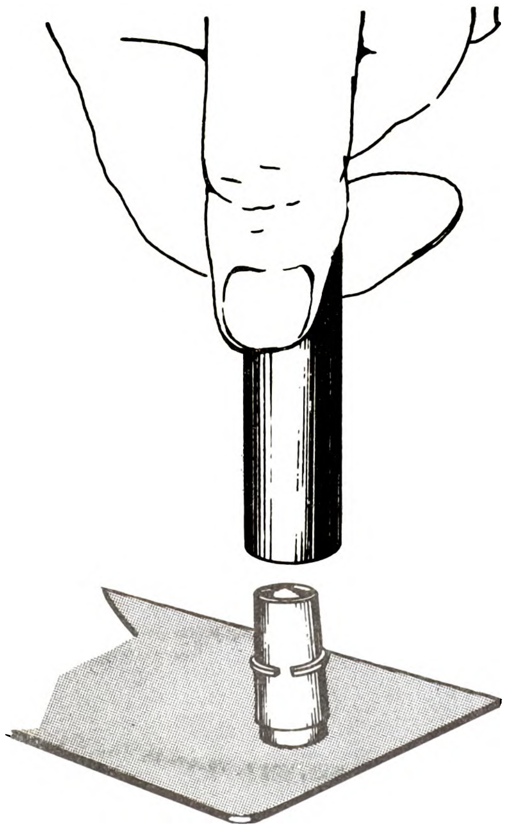

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Figure 10-24.—Installing snapring behind shoulder of grommet.

Receptacle Damage

Remove the attaching rivets, using standard removal procedures, in replacing the damaged receptacle. The new receptacle, which should be identical to the original, is then riveted into place.

DZUS FASTENER REPAIR

Dzus fasteners are of two types—the light-duty type and the heavy-duty type. The main difference in repairing is that the heavy-duty type requires an additional operation, as the retaining grommet must also be removed and replaced. The S-shaped spring is replaced if damaged or broken.

Installation

The light-duty Dzus fastener (fig. 10-25) is installed in the following three steps: First, the hole is dimpled, using a special set of dies; second, the correct size of stud is then inserted in the dimpled hole; and third, using another set of dies, the dimpled material is then forced into the undercut of the stud, which locks the stud in place.

The heavy-duty Dzus fastener is installed in the following four steps: First, a hole is drilled to the proper size, and the grommet is inserted; second, the grommet is then set (partially flared); third, the correct size fastener is then inserted through the grommet; and fourth, using a set of dies, the grommet material is flared, forcing the grommet to clinch the undercut part of the stud and the panel. This clinching action locks the stud position.

Removal

The light-duty Dzus fastener may be removed by placing the stud over a hole in an anvil and striking it with a hammer and drift punch. After the broken stud is driven out, the hole will be too large and will be dimpled on the wrong side. This may be remedied by flattening the hole area with a hammer and redimpling with the proper size dimpling tool.

Removal of the heavy-duty Dzus fastener requires a different procedure, as a grommet is used in the hole and must be cut away before the damaged stud can be removed. Insertion of a new grommet is necessary before installing a new stud. The heavy-duty Dzus fastener may be removed by cutting away the grommet, using diagonal cutter type pliers. The old fastener is then free to fall out of the hole. Inspect the hole area for damage and repair as necessary. The new fastener and grommet are then reinstalled in the original hole, as described previously.

Repair of the Hole

When the hole is too badly worn to permit reinstallation of the same size heavy-duty fastener, it is recommended that a lap patch be

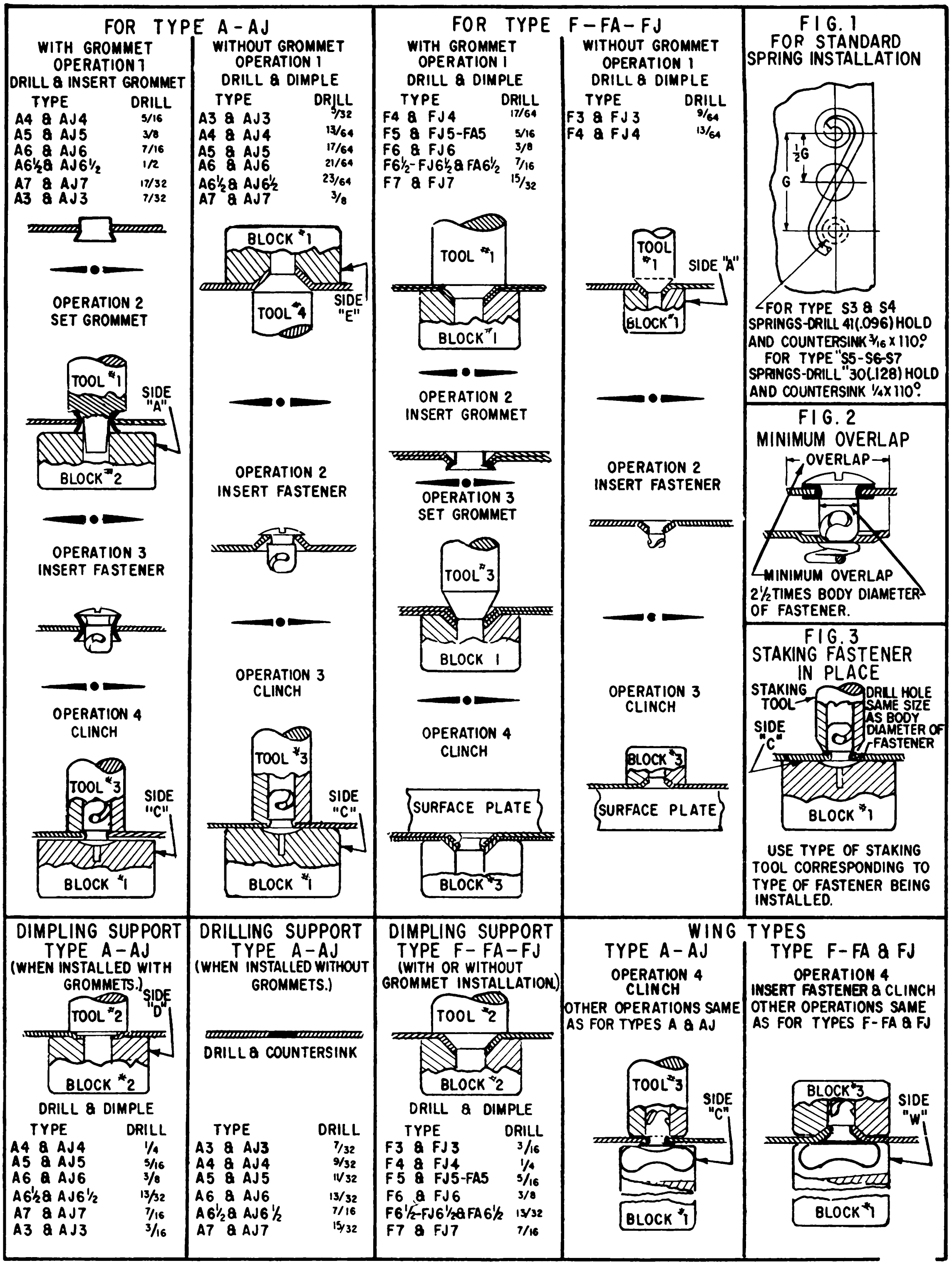

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Figure 10-25.—Dzus fastener installation instructions.

installed over the old hole and a new hole cut in the lap patch. The new fastener is then installed in the lap patch.

Repair of Spring

When a spring is broken or damaged, it should be replaced with a new and identical spring. Different spring heights are available for each fastener. There are also special springs which are used for installation in box corners and in panels which would be subjected to either horizontal or vertical movements.

AIRLOC FASTENERS

The Airloc assembly consists of the receptacle, stud, and cross pin as illustrated in figure 5-26 (chapter 5). The repair of this fastener is normally made by complete replacement of the damaged parts. The stud and cross pin should never be reused due to the press fit, which is necessary for cross pin retention.

Installation Procedures

As stated in chapter 5, the Navy normally uses Nos. 2, 5, and 7 Airloc receptacles. Each receptacle is held in place by rivets. The No. 2 receptacle is installed using 3/32-inch rivets; No. 5 requires 1/8- or 3/32-inch rivets; and No. 7 uses 1/8-inch rivets. Receptacles with flat rivet holes may be replaced by a receptacle with countersunk holes.

The stud normally comes in two head types—the countersunk head and the round head. (See fig. 10-26.) If round head studs are not available, the outer sheet may be dimpled and the countersunk head stud substituted. The head of the stud is stamped to indicate the total grip length. The studs are available in various lengths which are in increments of ten-thousandths of an inch.

To select the proper stud, the ASH must determine the total grip length. To obtain this, add the thickness of the inner structure and outer panels, doors, gaskets, reinforcements, etc., in thousandths of an inch. Add to this, 0.010 inch to allow for wrinkling and warpage of material. Select the nearest even 0.010 inch above the total for the proper length of stud.

NOTE: When using a floating type receptacle, add to the preceding measurements 0.020 inch for the No. 2 receptacle or 0.030 for the Nos. 5 and 7 receptacles.

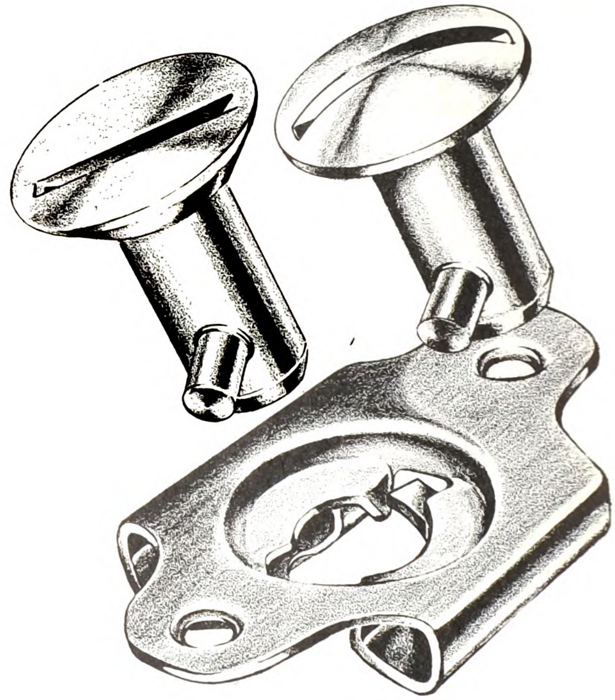

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Figure 10-26.—Airloc stud head shapes—countersunk and round.

After determining the correct length of stud, insert the new stud into the panel or sheet. Using the special Airloc tool, press the cross pin into the stud hole, as shown in figure 10-27.

When Airloc fasteners do not fasten properly and the studs are known to be the correct length, excess misalignment is normally the cause. This condition can often be corrected by removing the panel and fastening the studs in a different sequence. Fastening the difficult studs first, or by starting in the middle of the panel and working toward each end, usually corrects this condition.

Removal

Removal of damaged receptacles is accomplished by removing the rivets, using standard removal procedures. The stud is removed by pressing out or clipping off the cross pin. The cross pins for 1-inch and 1 1/8-inch studs are normally removed by pressing out, using special

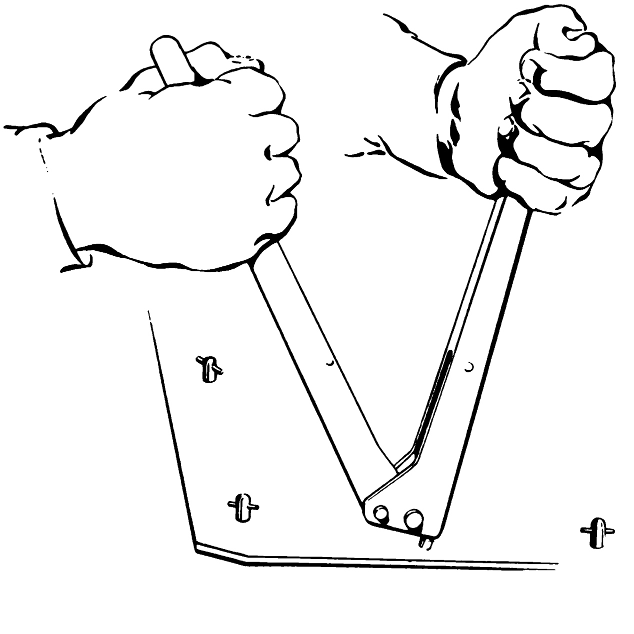

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Figure 10-27.—Inserting cross pin, using special Airloc tools.

hand pliers. (See fig. 10-28.) The cross pin for 3/4-inch studs may be removed either by using the hand pliers or by clipping off the cross pin.

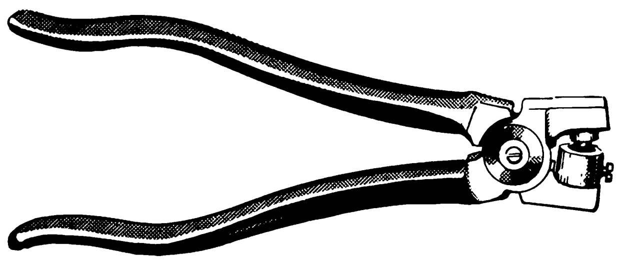

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Figure 10-28.—Hand pliers for removing cross pin.

BODY AND FENDER REPAIRS

As a result of carelessness and accidents, the body panels and fenders of certain items of support equipment are damaged. It is the responsibility of the ASH to correct these damaged parts. In some cases, the damaged area may be repaired, while in cases of severe damage it may be more feasible to replace the part. The size of the damaged area, the urgency of the repair job, and the availability of the required parts are all factors which must be considered when deciding whether to repair or replace the part.

The ease and the speed with which body and fender repairs are made depend largely on starting the repair in the correct manner. When done correctly, the amount of dinging (explained later), shrinking of metal, hand filling, and sanding will be kept to a minimum.

The damaged area should be closely examined to determine how the item of equipment was struck to cause the damage. When a collision occurs, there will be a major depression in the panel followed by a buckled area and then a series of ridges. The damage should be corrected in the reverse order in which it occurred. Thus, pressure should first be applied at the ridge furthermost from the point where the panel was struck. (See fig. 10-29.)

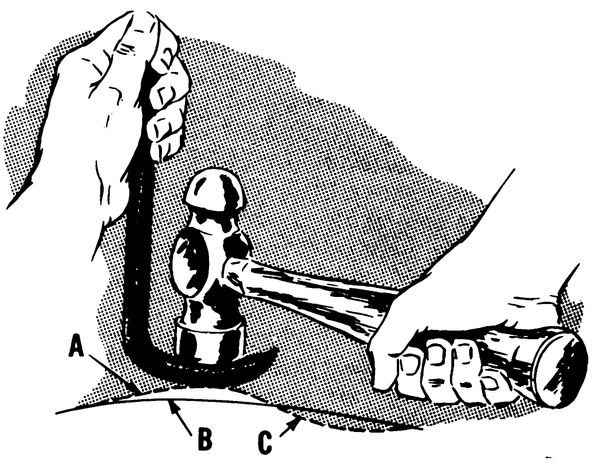

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Figure 10-29.—Removing dent from body panel.

Assume that the original form of the panel is shown at line (A) in figure 10-29. The depression at the broken line (B) is where the panel was struck, and (C) is the ridge formed last. Since the ridge at point (C) was formed last, it should be treated first. Place a spoon on top of the ridge, as illustrated in figure 10-29, and strike the spoon with a hammer. Follow the ridge with the spoon and hammer. As the ridge is removed, the major depression

at (A) will spring back close to the original contour of the panel. The remaining dents can then be removed with a dolly block and hammer.

Select a dolly block with the same general curvature as the panel being straightened. Hold the block under the panel and strike the high point of the dents with a hammer. A planishing hammer is normally used for this operation. The hammer blows should be light, as heavy blows tend to make the metal thinner, causing it to stretch. Therefore, several light blows should be used rather than a few heavy ones. This process of body work is called DINGING.

A file can be used to show the high and low spots in the panel. Use the file to make light cuts across the required area. The spots where the file cuts the heaviest probably require more attention with the dolly and hammer. Any slight roughness that cannot be removed with the dolly and hammer can be smoothed out with a power sander.

PATCHING BODY PANELS

When body panels have rusted through or are dented in such a way that it is difficult to remove the dents, the damage can be repaired by cutting out the damaged area and welding in a new section of sheet metal or by using one of the many commercial methods that have been developed. One of the popular commercial methods is to use sheets of special fabric. The surface to be repaired must first be thoroughly sanded. The fabric is then dipped in a special solution, and stretched over the damaged area.

After drying, the fabric adheres closely to the damaged surface. It is then given a coat of special "liquid" metal. When the metal becomes hard, it can be sanded and finished in the usual manner. Fiberglass and various plastic materials have been developed that are also satisfactory for patching. The manufacturer's instructions and recommendations must be closely followed when using these materials.

Lead solder is used extensively for filling small dents and smoothing rough surfaces which are difficult to straighten completely with a dolly block and hammer. Soldering was one of the earliest methods of filling dents in fenders and body panels. When properly applied, lead solder is very effective and satisfactory. The preparation of the damaged area is very important. The area must be thoroughly cleaned and tinned before applying the solder.

When it is determined that it is more economical to replace a panel than to repair it, rough out and shape the damaged area, making sure that the undamaged portion is in correct contour and is not sprung out of alignment. Measure the piece of metal to be replaced. Scribe a line on the damaged panel, using the new panel as a template. Then cut the damaged panel out around the scribed line.

Clamp the new section in with C-clamps; then weld the section in place. With a grooved dolly, hammer the weld so that it is below the surface of the surrounding panel. Sand the area around the weld and fill the groove, covering the weld with solder or one of the commercial filling materials. Sand and finish the affected areas as previously described.

After the repair is completed the affected surface is then painted. Painting procedures are discussed in chapter 17.

STEAM CLEANERS

As mentioned in chapter 4, steam cleaners are used to clean and degrease equipment and components, aircraft, machinery, machine parts, and other items which are not subject to damage through the application of moisture. Most models can be used as a steam cleaner or as a high-pressure hot or cold water washing and rinsing unit. In addition, they are usually equipped with a cleaning solution system whereby soap or other approved cleaning compounds may be automatically mixed with the steam or water.

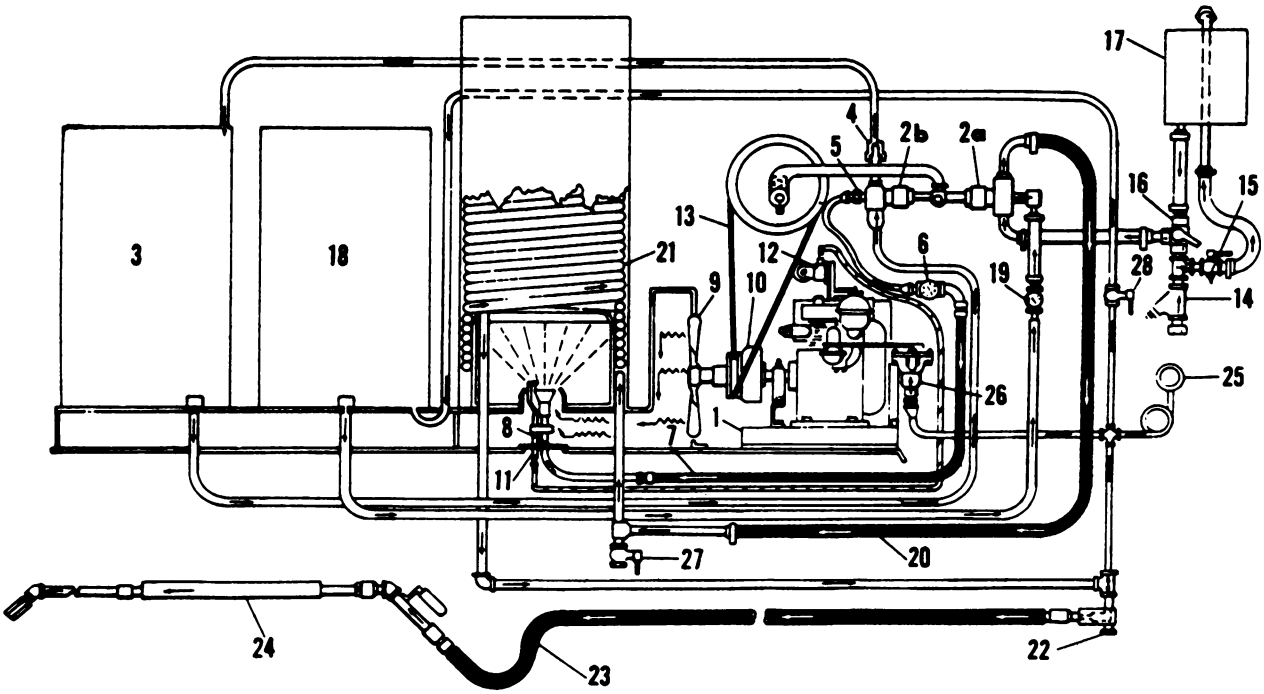
The main source of power for some models of steam cleaners is a self-contained gasoline engine, while others are electrically operated. Although the ASH is primarily responsible for the maintenance of steam cleaners, the maintenance of the power sources is the responsibility of the ASM and ASE. The steam cleaner discussed in this section is a gasoline engine driven unit. Electrically operated models are very similar in design and operation.

COMPONENTS

Figure 10-30 is a schematic diagram of the steam cleaner system. The major components are described in the following paragraphs.

Power Source

The main power source is a one-cylinder gasoline engine with a magneto ignition system.



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1.	Gasoline engine assembly.	15.	Water inlet valve.
2a.	Duplex pump—water and solution.	16.	Water selector valve.
2b.	Duplex pump—fuel.	17.	Water tank.
3.	Burner fuel tank.	18.	Solution tank.
4.	Fuel bypass orifice.	19.	Solution valve.
5.	Antisiphon check valve.	20.	Water alleviator hose.
6.	Fuel valve.	21.	Heater coil.
7.	Fuel cushion hose.	22.	Fusible plug.
8.	Burner assembly.	23.	Vapor hose.
9.	Blower fan.	24.	Cleaning gun.
10.	Centrifugal clutch assembly.	25.	Pressure gage.
11.	Burner electrode.	26.	Pressure control switch assembly.
12.	Burner magneto assembly.	27.	Coil drain and relief valve.
13.	V-belt.	28.	Solution stirring valve.
14.	Water strainer.		

Figure 10-30.—Schematic diagram of steam cleaner.

It furnishes power to drive the duplex pump assembly, the burner magneto, and the blower fan. A governor maintains a steady engine speed during operation.

Clutch and Fan Assembly

A centrifugal clutch couples the engine to the V-belt drive pulley of the system. The

clutch disengages the engine from the system when the engine is at idle speed, and automatically engages the engine with the system at operating speed. The blower fan, secured to the V-belt pulley, supplies air to the heater coil combustion chamber.

Duplex Pump Assembly

An eccentric crank, attached to the V-belt driven pulley, actuates two reciprocating piston type pumps. The pumps supply fuel to the burner and a mixture of water and cleaning compound to the vapor generator. Each pump housing is equipped with an inlet and an outlet check valve.

Water Tank

The water tank serves as a pressure relieving reservoir for pressurized tap water. As water is pumped from the water tank into the system, a float valve admits more water from the tap supply to maintain the water level.

Burner Fuel Tank

The 12-gallon fuel tank contains the fuel (kerosene or number 2 fuel oil) for the vapor generator. An outlet 2 inches above the bottom of the tank provides a sump for the collection of water and sludge. A fuel strainer is provided on the outlet side. Fuel is pumped from the fuel tank to the vapor generator burner through an antisiphon check valve and a metering valve. Excess fuel is channeled through a bypass orifice back to the fuel tank.

Burner Assembly

The burner assembly is located under the heater coil of an updraft combustion chamber and serves to vaporize and ignite the fuel. The burner magneto supplies the ignition spark to an electrode clamped to the burner.

Burner Magneto Assembly

The burner magneto is driven by the outside surface of the engine pulley V-belt. This magneto maintains continuous fuel ignition whenever the engine is running.

Solution Tank

The solution tank has a capacity of 12 gallons. This amount of cleaning solution is sufficient to sustain a minimum of 4 hours of continuous operation at approximately 25 percent of the full volume range of the cleaning solution metering valve. A panel mounted stirring valve permits the cleaning solution to be mixed and heated in the cleaning solution tank.

Heater Coil

Located in the vapor generator above the burner, the heater coil is a continuous tube, capable of withstanding high pressures. Water and a cleaning solution pumped into the heater coil are brought to a high temperature and forced through the coil into the delivery hose at high pressure.

In addition to the major components, the following accessories are provided with each steam cleaner:

1. A vapor (delivery) hose. This flexible hose carries the vapor mixture of water and cleaning solution from the heater coil to the cleaning gun.
2. The cleaning gun assembly with a 2-inch flat nozzle and a 4-inch flat nozzle. The gun assembly, used to direct the vapor on objects to be cleaned, has an insulated handle.
3. A water intake hose for water supplied under pressure.
4. A suction hose with a foot valve for pumping water from unpressurized sources.

OPERATION

The basic requirements of water, air, fuel, and cleaning compound are delivered to the steam cleaner by means of the gasoline engine (1). (Refer to fig. 10-30.) The duplex pump (2a), driven by the engine, pumps water mixed cleaning compound to the heater coil. A second piston (2b) of the pump draws fuel from the tank (3) and delivers it to the burner jet tip. The engine powers the blower fan (9) which delivers air to the burner deflector where it mixes and vaporizes the fuel. The magneto (12), which supplies voltage to ignite the fuel, is also powered by the engine.

As fuel is forced from the pump, it is split into two streams at the fuel bypass orifice (4). One stream returns to the fuel tank. Fuel bypassing is necessary at all times, since the

capacity of the pump is much greater than the capacity of the burner. The other stream flows through the antisiphon check valve (5) to the fuel valve (6). The fuel valve permits the operator to regulate the amount of fuel reaching the burner, which determines the working pressure of the vapor spray.

Fuel pumped through the fuel valve flows through a cushion hose (7), which absorbs pump pulsations, to the jet tip of the burner (8), where it vaporizes and mixes with air from the blower fan (9). The vaporized fuel is ignited by a spark at the burner electrode (11). The burning fuel vapor heats the water and cleaning solution in the heater coil which is located in the combustion chamber.

At the same time, cleaning solution may be drawn from the solution tank (18) through the metering valve (19) to the pump. The operator regulates the proportion of the cleaning solution to water by adjusting the solution valve.

The mixture of water and cleaning solution flows from the pump through a water alleviator hose (20), which absorbs pump pulsations, to the heater coil inlet. Raised to high temperature and pressure in the heater coil (21), the partially vaporized water and solution mixture is forced from the heater coil outlet.

A tee routes the mixture to the vapor hose (23) and cleaning gun (24), and to two pressure-sensitive devices. One of these devices is the pressure gage (25), which gives the operator an accurate indication of system pressure. The other device is the pressure-sensitive switch (26). A plunger on the switch is actuated by pressure and throttles down the engine when the pressure reaches 150 psi. The centrifugal clutch (10) then disengages the system from the idling engine.

Another pressure-sensitive device is located at the heater coil inlet. The coil drain and relief valve (27) opens automatically to relieve excessive pressure from the system. It may also be opened manually to drain the system.

To operate the steam cleaner, it is essential that the operator knows how to perform every operation. The operation includes the selection and mixing of the cleaning solution, and starting, operating, and stopping the unit.

Cleaning Solutions

There are several types of cleaning compounds available for use with the steam cleaner. Some of these compounds are described in chapter 17. However, the Operation Instructions for the specific steam cleaner should be consulted for the proper cleaning compound to be used for each type cleaning job.

The proportion of compound to water may vary. Follow the instructions which accompany the container to determine the correct proportion. Some compounds may be mixed in the solution tank. However, dry powder compounds tend to clog the lines of the unit and, therefore, should be mixed in a separate container before pouring into the solution tank.

Starting the Steam Cleaner

After the solution tank is filled with the correct solution, the steam cleaner is started following the procedures listed below:

1. Connect the vapor hose and cleaning gun, with the desired nozzle, to the steam cleaner.
2. Connect the water supply to the water inlet and make certain that water is available.
3. Close the coil drain and relief valve.
4. If the unit has not been used for several days, the pump check valves may be set in position. A slight tap against the pump body will insure operation.
5. Start the engine of the steam cleaner.
6. If necessary, mix the cleaning solution by opening the stirring valve for approximately 2 minutes.
7. Turn the solution valve counterclockwise to achieve the desired proportion of cleaning solution to water.

CAUTION: The steam cleaner should be operated only in a well-ventilated area.

Operating Procedures

The operating pressure, the proportion of cleaning compound to water, and the type of nozzle are the major items of concern for the efficient operation of the steam cleaner. The operating pressure may be adjusted by turning the fuel valve. The useful pressure range is 50 to 120 psi. For most cleaning operations, the pressure should be set at 80 to 100 psi. To increase the pressure, the fuel valve handle is turned counterclockwise. To reduce pressure, the fuel valve handle is turned clockwise.

A suitable proportion of cleaning compound to water may be obtained by adjusting the solution valve. The solution valve handle is turned counterclockwise to increase the proportion of

cleaning compound and turned clockwise to decrease the proportion.

For cleaning intricate surfaces, the gun should be used without a nozzle. The gun should be held 1 to 3 inches from the surface and moved rapidly with a brushing action to thoroughly cover the surface.

The 4-inch flat nozzle should be used for light cleaning of flat surfaces. The nozzle should be applied directly to the surface with the slot downward. The nozzle should be moved back and forth, covering an area the width of the nozzle at each stroke. Do not move the nozzle sideways.

The 2-inch flat nozzle should be used for difficult cleaning of flat surfaces. The 2-inch nozzle is applied in the same manner as the 4-inch nozzle.

Stopping the Steam Cleaner

To stop the steam cleaner, the following steps must be performed in the indicated sequence:

1. Turn the fuel valve and solution valve completely off (clockwise).
2. Wait until the water issues from the cleaning gun, then press the stop button.
3. Close the engine fuel shutoff valve.

CAUTION: If the steam cleaner is exposed to freezing temperatures, the unit must be drained after operation.

INSPECTION AND MAINTENANCE

Servicing and maintenance of the steam cleaner is generally limited to periodic inspection of the power source, the fuel burner, supply tanks, hoses, and tubing; adjustment, and setting of controls; and lubrication of moving parts. The applicable Service and Overhaul Instructions should be consulted for the interval and extent of the inspection.

The unit should be cleaned frequently. In most cases, the cleaner can most efficiently be used to clean itself. The strainers should all be removed and cleaned at regular intervals. Soot deposits must be cleaned from the heater coil from time to time. If the deposits are light, they may be burned off by operating the steam cleaner with a low fire for a short time. If the soot deposits are heavy, they can be washed off with cleaning vapor from the steam cleaner.

The heater coil, water and solution lines, and vapor lines of the steam cleaner must be delimed at intervals which depend upon the conditions of use (approximately monthly under normal use with soft water). The cleaner is delimed in the following manner:

1. Place a clean 5-gallon container beside the steam cleaner.
2. Start the engine and operate the steam cleaner with the solution and fuel valves closed until the water issuing from the cleaning gun is free from solution.
3. Stop the engine and turn off the water at the source or remove the suction hose from the supply.
4. Disconnect the water hose at the inlet side of the water pump cylinder. Attach a 3/4-inch rubber hose of sufficient length to reach between the 5-gallon receptacle and the water inlet of the pump. Tie a layer of fine-weave cloth over the hose end and insert into the receptacle.
5. Pour 1 gallon of water into the receptacle and insert the nozzle of the cleaning gun into it.
6. Start the engine, making sure that the fuel and solution valves are completely closed.
7. Slowly pour 2 quarts of deliming agent into the receptacle. (The deliming agent is usually listed in the Operation Instructions for the steam cleaner. Hydrochloric acid is a common chemical used for this purpose.)

CAUTION: Deliming agent is hazardous. Avoid contact with the skin. If contacted, flush immediately with fresh water.

8. Close the engine fuel valve at the sediment bowl.
9. When the engine stops running, wait 5 minutes and then turn the large pulley slowly by hand to cycle the pump a few times. Wait for 2 more minutes, and again slowly cycle the pump. Repeat the hand cycling operation five more times, pausing at least 1 minute between operations.
10. If the lime deposits are exceptionally heavy, discard the liquid in the receptacle and repeat steps (1) through (9).
11. Remove the lime deposits from the water tank with deliming agent and a wire brush. Flush the tank with water for several minutes after deliming.
12. Remove the hose from the water pump inlet and reconnect the water hose. Turn on the water at the source or replace the suction hose in the water supply.

13. Open the engine fuel valve and start the engine. Pump clean water through the system for about 5 minutes to flush out the deliming agents. Then stop the engine.

14. Remove the fusible plug from the vapor outlet orifice tee. Restart the engine and pump water through the tee. Stop the engine and reinstall the fusible plug.

15. Start the steam cleaner. Open the fuel valve to achieve operating pressure and fully open the solution valve. Operate the unit for 5 minutes to neutralize any deliming agent remaining in the system.

DRY HONERS

As stated in chapter 4, the maintenance of dry honing machines is the responsibility of the ASH. The portable machine represented in this section is a compact, self-contained, lightweight unit used for honing small workpieces and for the safe and convenient removal of corrosion products from aircraft, aircraft components, and many other metal surfaces. The machine is air operated and can be used in shorebased or shipboard operations without loss of abrasive material to the atmosphere.

COMPONENTS

The dry honing machine (fig. 10-31) is composed of the following principal components mounted on a two-wheel carriage assembly:

1. Dust collector.
2. Abrasive reclaiming system.
3. Abrasive hopper (storage tank).
4. Abrasive supply and return hoses.
5. Blast gun assembly.
6. Pneumatic system.
7. Control and regulator valves and gages.
8. Accessories.

A hose rack and storage compartment are provided on the front of the dry honing machine for storage of hoses, brushes, and accessories.

Dust Collector

The dust collector consists of a number of cloth filter bags, mounted within the dry honing machine, and arranged so that dust-laden air from the abrasive reclaiming system must pass through the filter bags before being discharged through the exhauster. The filter bags are shaken by manual operation of the dust bag rapper, shaking loose the accumulated dust that drops down to the dustbox at the bottom of the machine. Releasing two spring latches permits the dustbox to be removed for dust disposal.

Abrasive Reclaiming System

This system is mounted directly above the abrasive hopper, and consists essentially of a cyclone separator into which abrasive and debris (from the abrasive return hose) enter tangential. This tangential entry imparts a cyclonic, or circular, action to the airstream, causing the abrasive to drop out of suspension, to the bottom of the cyclone separator. There, a vibrating screen, powered by an air-driven vibrator (mounted at the center of screen on a supporting frame), presents a fine-mesh filter to remove any oversize particles from the fine abrasive. The extent of screen vibration is preset by an orifice in the air line. The fine abrasive passes down through the vibrating screen to the abrasive hopper for reuse.

Abrasive Hopper (Storage Tank)

The abrasive hopper is cone-shaped for efficient direction of abrasive flow. The hopper is quickly and easily removed by release of two spring clamps. The normal capacity of the hopper is 5 pounds of abrasive material. A feed tee is located at the bottom of the hopper. The abrasive flows into the feed tee in the center of the feed-valve body. The feed tee is accurately sized to meter the proper amount of abrasive.

Abrasive Supply and Return Hoses

The abrasive supply hose is a 20-foot length of 5/8-inch ID transparent plastic hose, which permits direct observation of abrasive flow. It is attached to the aerator and feed tee, and conveys aerated abrasive to the blast gun assembly. The abrasive return hose is 20 feet long and returns used abrasive and debris from the blast gun assembly to the abrasive reclaiming system. A transparent plastic suction bypass line is provided to remove abrasive from the abrasive supply line when the machine is shut off so as to eliminate hose surging when blasting is started again.

One end of the suction bypass line is connected to the feed tee opposite the abrasive supply hose connection, and the other end of the line extends up into the abrasive hopper. This line terminates in the hopper above the

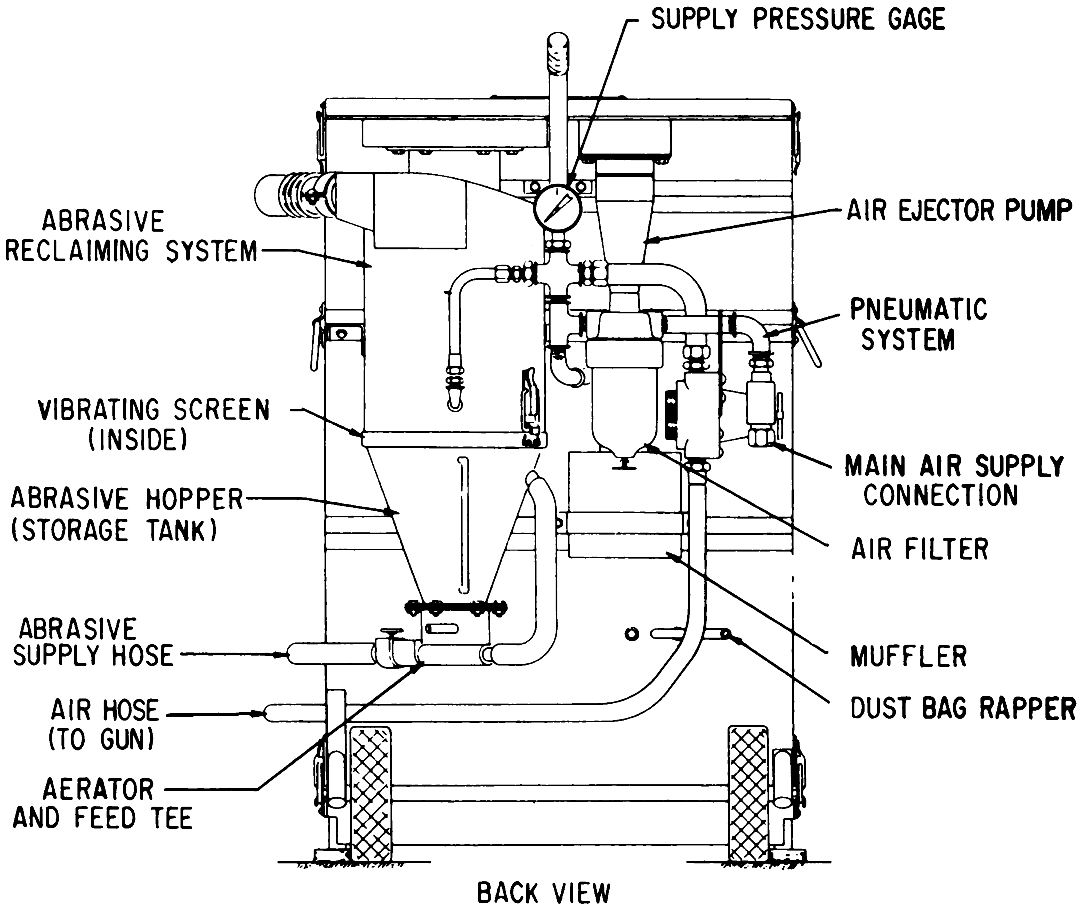

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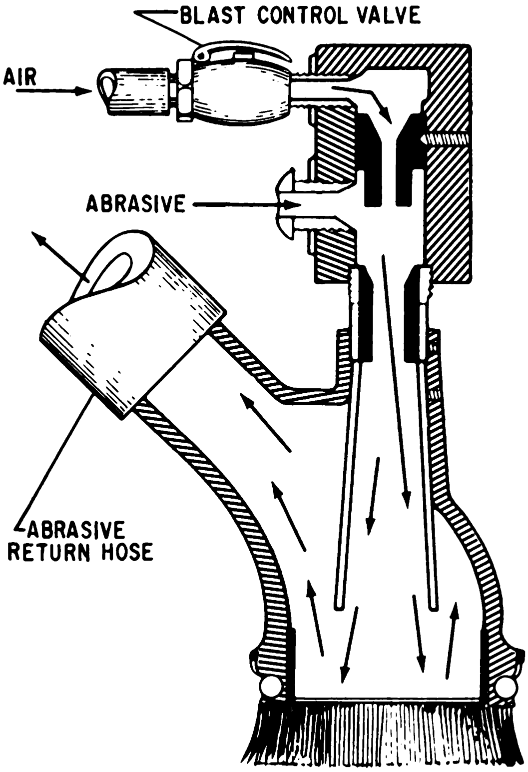
Figure 10-31.—Portable dry honing machine—back view.

abrasive level. The open end is protected from abrasive by an interior baffle. When blasting stops, the exhauster remains in operation. This suction causes the air to flow backwards through the blast gun nozzle, abrasive supply hose, feed tee, and bypass line, conveying any abrasive in the hose back onto the abrasive hopper. When blasting, airflow is reversed and the bypass line insures a balanced pressure between the storage hopper and the feed-tee housing so that the abrasive will fall freely through the feed tee into the abrasive supply hose.

Blast Gun Assembly

The blast gun assembly consists of a hand-held gun, blast control valve, nozzle assembly, and connections for air, abrasive supply, and abrasive return hoses. The blast gun assembly draws the abrasive material from the abrasive supply hose, accelerates the abrasive through the blast nozzle, and directs it against the workpiece. This is accomplished through the gun which employs an eduction system. Compressed air is expended through an air jet to create a low-pressure area in the gun housing. The abrasive supply hose is connected to the gun housing at the point of this low-pressure area. (See fig. 10-32.) Aerated abrasive enters the gun at this point, where it mixes with the high-velocity airstream. It is then further inducted through a tungsten-carbide-line blast nozzle directed at the work. Abrasive and debris do not escape to the atmosphere, but are returned through the abrasive return hose.



AM.60
Figure 10-32.—Blast gun assembly.

Pneumatic System

The pneumatic system includes a main air supply connection at which is attached the external compressed-air supply, interconnecting tubing, and air filter with a drain cock for removal of liquid from the compressed air, and an air ejector pump that creates the necessary vacuum to return the used abrasive from the blast gun assembly to the filter bags. The dry honing machine operates satisfactorily on air pressures ranging from 80 to 100 psi and airflows ranging from 80 to 90 cfm.

Control and Regulator Valves and Gages

The supply pressure gage indicates the compressed-air supply pressure. The 150-pound maximum variable pressure regulator is operated to adjust the air supply pressure to the desired pressure before entering the airhose to the blast gun assembly. This pressure is indicated on the regulated blasting pressure gage.

Accessories

The following accessories are provided with the dry honing machine:

1. Flat surface (straight) brush.
2. Outside corner brush retainer.
3. Outside corner brush.
4. Inside corner brush.
5. Uneven surface blaster.

ABRASIVES

There are two types of abrasives used in the dry honer—glass beads and aluminum oxide. As a general rule, glass beads are used on aluminum and magnesium materials, and aluminum oxide is used on steel material. However, the Operating Instructions for the dry honer should be consulted for the proper selection of abrasives for use with different types of materials.

OPERATING PROCEDURES

To operate the dry honer, fill the abrasive hopper with a full charge of the appropriate abrasive (5 pounds). Less than full abrasive charges may be used for touchup work or for dry honing either highly corroded or relatively small areas of steel. Contaminated abrasives should be thrown away after completion of dry honing operation. No less than one-half charge (2 1/2 pounds) should ever be used.

CAUTION: The vibrating screen, porous filter, abrasive reclaiming systems, and abrasive supply hose must be cleaned with compressed air whenever types of abrasives are changed (glass beads to aluminum oxide or vice versa). Do NOT use solvent or chemicals to clean components of the dry honing machine.

After filling the machine with the correct abrasive, turn the regulator adjusting screw to the full open position, then turn on the external air supply valve. Set the pressure regulator to the desired pressure by placing the gun against a scrap piece of metal or rubber and operating the gun. The blast pressure can then be adjusted with the machine in operation.

Hold the blast gun against the surface to be dry honed and press the blast control valve at the gun. Move the gun smoothly over the

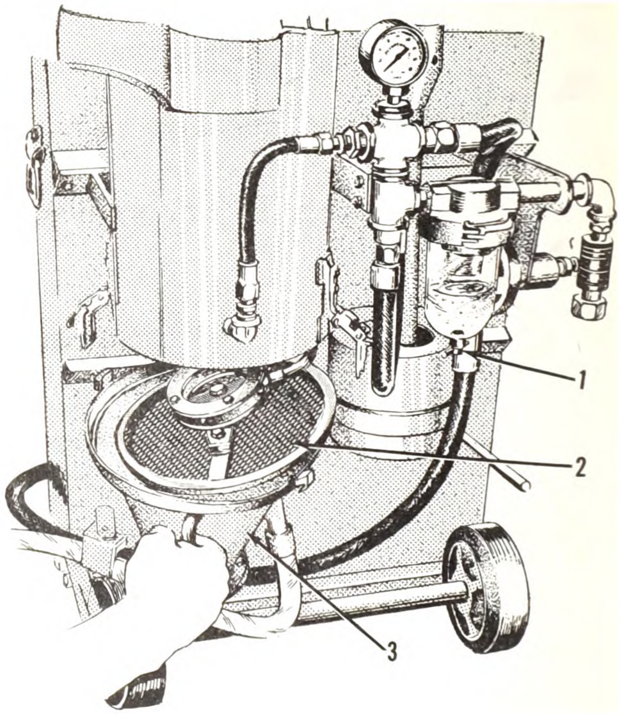
surface in a uniform manner. Move the gun in a smooth pattern of overlapping strokes, advancing approximately 3/4 inch at each pass. Move the brush in a small circular path at the end of each stroke so the bristles tend to roll smoothly from one direction to the other.

NOTE: Workpieces must be free from oil, water, and excessive debris. Parts that are covered with oil, solvent, or water emulsion must be cleaned prior to dry honing, as heavy deposits tend to clog the abrasive.

To prevent loss of abrasives, fully release the blast control valve each time the dry honing operation is stopped and/or before the gun is raised from the surface.

At the end of each 2 hours of operation, shut off the air supply to the machine and shake down the filter bags by swinging the dust bag rapper down and sharply returning it to the normal position. Repeat this rapper action for 20 quick strokes. After shaking down the filter bags, empty the dustbox.

Any accumulation of moisture in the air filter should be drained by opening the drain cock at the bottom of the filter. (See item 1, fig. 10-33.) This should be accomplished at the end of each 4 hours of operation, or whenever an accumulation of moisture is visible in the filter.



AS.689

1. Air filter drain cock.
2. Filter screen magnet assembly.
3. Abrasive hopper.

Figure 10-33.—Abrasive hopper and air filter.

INSPECTION AND MAINTENANCE

As stated in chapter 4, the dry honer is one of the many types of support equipment that is under the Planned Maintenance System. Therefore, Maintenance Requirements Cards (MRC's) are provided for this type of equipment. The Preoperational Requirements Card for the dry honer is illustrated as an example in chapter 4. (See fig. 4-25.) Figure 10-34 illustrates, in part, the Calendar Maintenance Requirements Cards. Military Requirements for Petty Officer 3 & 2, NavPers 10056 (Series) should be consulted for a description of the Planned Maintenance System and for the explanation of the information contained in each block and column of the cards.

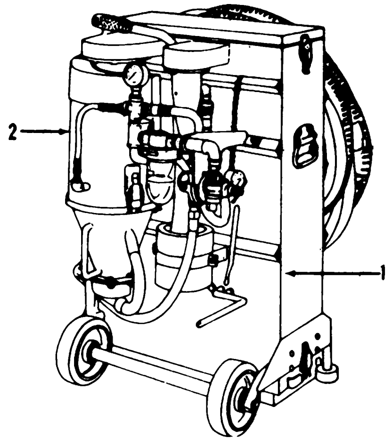
In addition to the three cards shown in figure 10-34, the complete set of Calendar MRC's for the dry honer includes several other cards. These cards, several of which are common for all Calendar MRC's pertaining to support equipment, are described in the following paragraphs.

1. Title card. This is the first card of the set and contains the publication number, the type MRC set, the type and model of the item of equipment, and the date of issue, including the latest change date.

2. A card. This card is printed on the back of the title card. Its main purpose is to list the cards of the set that have been changed, deleted, or added. The title card and A card are similar to the cover and change pages of manual publications. A new title and A card is issued with each change to the MRC set. All card changes are listed by number on the A card. Cards affected by the current change are preceded with an asterisk. Information concerning the procurement of additional sets of MRC's is also included on the A card.

WORK AREA

1. Cabinet Assembly
2. Hopper and Air Controls



CARD	PUBLICATION NUMBER	CARD SET DATE	CHANGED
viii	NAVAIR 17-600-22-6-4	1 February 1968	

CARD 1	TIME 00:15	RTG. ASH NO. 1	13 WEEKS	CABINET ASSEMBLY	ELEC PWR N/A HYD PWR N/A
TASK MIN.	**WORK AREA**	**MOS. 6373 NO. 1**	**PUBLICATION NUMBER** NAVAIR 17-600-22-6-4	**CARD SET DATE** 1 February 1968	**CHANGED**
			SPECIAL TOOLS/EQUIPMENT Air Source (80 to 100 psi) Gun, Air		
2.0	1		1. Wheels, support legs and handle for distortion and secure attachment; tires for cuts and excessive wear.		
1.0	1		2. Cabinet for corrosion and obvious damage.		
			WARNING: Wear goggles and respirator when cleaning components of the dry honing machine with compressed air.		
			NOTE: Do not use solvents or chemicals for cleaning; use compressed air only.		
10.0	1		3. Filter bag: a. shake down filter bag. b. remove bottom dust box cover and empty. c. remove top dust box cover. d. remove filter bag, empty and clean with compressed air; bag for wear and deterioration.		

TASK MIN.	WORK AREA	CARD 1.1	PUBLICATION NUMBER NAVAIR 17-600-22-6-4	CHANGED	ELEC PWR N/A HYD PWR N/A
			e. install filter bag. f. covers for distortion; seals for deterioration and secure attachment. g. install covers; latches for secure attachment and proper operation.		
2.0	1,2		4. Unit for corrosion; paint for chipping and peeling.		

AS.690

Figure 10-34.—Sample Calendar Maintenance Requirements cards—portable dry honer.

3. Introductory cards. These cards are umbered consecutively, front and back, in owercase Roman numerals; that is, i, ii, iii, v, etc., as required. The information on these ards includes an introduction, the interval of alendar maintenance and overhaul, format escription, definitions, special tools and equipment list, consumable maintenance materials ist, replacement parts list, and work areas.

The introduction contains the following statement which should be emphasized: "These aintenance requirements establish the minimum requirements necessary to maintain this quipment in a satisfactory and operationally eady condition and will be used in performing he inspection to insure that no item is overlooked. They do not contain instructions for epair, adjustment, correcting defective conditions, or troubleshooting to find causes of alfunctions."

Notice that the MRC's establish "minimum equirements." This means that local commands cannot deviate from the established requirements; however, they may increase the cope or frequency to properly support varying equirements or environmental conditions. Appropriate technical manuals should be consulted or repair, adjustment, troubleshooting, etc. of he equipment. These manuals are listed on he introductory cards as Reference Publications. In the case of the dry honer, NavAir 7-5BM-1, Operation, Service, and Overhaul nstructions with IPB, is listed.

The interval of Calendar Maintenance and verhaul is scheduled in accordance with ours/starts and/or calendar intervals. The IRC's to be used for each Calendar Maintenance interval are listed by card number. In he case of the dry honer, only one interval (13 weeks) is scheduled. Thus, calendar maintenance is performed on this item of equipment t the end of each 13-week period. Since this s the only interval scheduled, all of the MRC's re used for each inspection. There is no verhaul Interval established for this item of quipment.

The card titled Format Description explains he information that appears in the blocks and olumns of the requirements cards. As stated reviously, this information is described and llustrated in Military Requirements for Petty fficer 3 & 2, NavPers 10056 (Series).

One section of the introductory cards gives efinitions of various terms used in presenting the required tasks on the MRC's. An understanding of these terms is very important for the safe and effective performance of calendar inspections; therefore, the definitions of these terms are presented as follows:

NOTE - An information item. The note may precede or follow the item to which it refers. (See fig. 10-34 for an example of a NOTE.)

CAUTION - Indicates danger to the equipment. The caution precedes the item to which it refers.

WARNING - Indicates danger to personnel. The warning precedes the item to which it refers. An example of a WARNING is shown in figure 10-34.

VISIBLE or EXPOSED - The term applied when inspection requires no further disassembly or movement of equipment, and no removal of doors or panels is required other than that specifically detailed.

EVIDENCE - An indication of an existing condition; for example, hydraulic fluid dripping from an enclosed section is evidence of a leak existing in that area.

DAMAGE - A harmful condition caused by an abnormal force or object.

SECURITY - An item firmly, positively, and safely attached in the approved manner.

SPECIFIED - Refers to a definite amount, operation, or limitation.

OBVIOUS - Easily seen or understood, clear to the eye or mind, not to be doubted.

PROPER - Used to define a "visual only" inspection where a more detailed requirement might be presumed to exist.

The next three sections of the introductory cards are separate lists of special tools and equipment, consumable materials, and replacement parts necessary to accomplish the requirements of the specific MRC set. The replacement parts list includes the quantity of parts that are to be replaced at specified intervals. This includes such items as seals and filter elements that must be replaced at specific intervals and certain components that require overhaul after specified time periods of operation. The items in these three sections are listed by nomenclature, part, type, or specification number, and quantity required for each interval of Calendar Maintenance. The special tools and equipment required to accomplish the Calendar Maintenance on the dry honer are: an air source (80 to 100 psi), an air gun, a hand oiler, and a spanner wrench. Lubricating oil, MIL-L-7870, is the only item

of consumable material that is required. No replacement parts are required.

The work area card for the dry honer is illustrated in figure 10-34. The work area numbers are used for reference on the requirement cards.

4. Requirements cards. These cards are the working items of an MRC set. These cards contain the pertinent information required by each maintenance man to complete each task. Data for each task includes a description; the time required to perform the task; the power, tools, equipment, and material requirements; and detailed information on such items as adjustments, pressures, and torque values.

The requirements cards pertaining to the cabinet assembly of the dry honer are illustrated in figure 10-34. Additional cards for the dry honer include a section on the inspection of hopper and air controls, lubrication, and operational check. The tasks concerning the inspection of the hopper and air controls are presented in a manner similar to that shown for the cabinet assembly. This includes detailed inspection of the hopper, cyclone and vibrator assembly, air ejector, regulator, air filter, gages, hoses, and fittings.

The lubrication card provides all information necessary for the complete lubrication of the equipment including the tools, equipment, consumable materials, etc. The location, nomenclature, and specification of lubricant are listed for each point requiring lubrication.

The lubrication cards for most items of support equipment include a lubrication chart which shows all lubrication points on an illustration of the equipment. Since the wheels of the dry honer are the only items that require lubrication, a lubrication chart is not required.

Some sets of MRC's contain several lubrication charts. For example, the requirements cards for a self-propelled item of equipment may be divided into several sections—powerplant, chassis, power train, etc. In this case, each section would contain a lubrication chart.

The operational check for the Calendar Maintenance of the dry honer is identical to the operational check on the Preoperational Requirements Card. (See figure 4-25, chapter 4.)

The tasks listed on the requirements cards are arranged in the most efficient order for accomplishment both by the sequential arrangement of the tasks on each card and the sequential arrangement of the cards. This arrangement is determined by such factors as interval of inspection, different systems, power requirements, etc.

No part of any scheduled maintenance is certified (signed off) on the Maintenance Requirements Cards; therefore, they may be used as many times as their condition permits.

Calendar inspections are documented on the single copy Maintenance Action Form (MAF). A detailed description of the MAF, including the type of data to be entered in each block, is presented in Military Requirements for Petty Officer 3 & 2, NavPers 10056 (Series). Remember, the MAF is a multiple-purpose form that is used to document many different types of maintenance actions. As a result, the documentation of some maintenance actions does not require entries in all blocks. For example, the MAF illustrated in figure 10-35 shows the entries required for the documentation of a Calendar inspection on the dry honer. The procedures involved in the documentation of this type maintenance action are described in the following paragraphs.

A single copy MAF is initiated by maintenance/production control and is forwarded to the check supervisor before the start of the Calendar inspection. This original single copy MAF serves as a control document and is held open until the inspection is completed and the item of support equipment is ready for operation. At this time, the check crew supervisor submits this control copy with a 1 in block 13 to indicate that one inspection has been completed. If required, the maintenance action is then entered in the appropriate log or record. The MAF illustrated in figure 10-35 is an example of a completed control copy.

Referring to figure 10-35, notice that blocks 14 and 15 (Manhours and Elapsed Maintenance Time) are blank. These manhours are documented on separate single copy MAF's by each work center participating in the inspection. In some cases, only one work center is involved, while in other cases, several work centers may be involved. In any case, each participating work center documents a separate MAF for that part of the inspection they accomplish. Most of the entries, including the Job Control Number (Block 1), on these MAF's are the same as those on the control copy. The following are the exceptions:

Block 5 - Work Center. The code of the work center which performs that part of the inspection described on the MAF is entered here.

MAINTENANCE ACTION FORM
OPNAV FORM 4790/40 (10-69) S/N-0107-770-4400

1. JOB CONTROL NUMBER ORG.	DATE	SER	SUF	2. TYPE EQUIP.	3. BU/SER NO.	4. ACTION ORG.	5. WORK CENTER	6. MAINT. LEVEL	7. ACTION DATE
A98	1336	A00		GLDF	678543	A98	950	☐ 1 ORG. ☒ 2 INT ☐ 3 DEP	1336

8. WORK UNIT CODE	9. WHEN DISCD	10. TYPE MAINT.	11. ACTION TAKEN	12. MAL	13. ITEMS PROC.	14. MAN-HOURS	15. EMT	16.
030	0	P	0	000	1			

20. REMOVED ITEM		21 INSTALLED ITEM	
.1 MFGR	.2 SERIAL NUMBER	.1 MFGR	.2 SERIAL NO.
.3 PART NUMBER	.4 TIME/CYCLES	.3 PART NUMBER	.4 TIME/CYCLES

B. DISCREPANCY	C. CORRECTIVE ACTION
DUE FOR CALENDAR INSPECTION	COMPLETED CALENDAR INSPECTION

D. ENTRIES REQUIRED			SIGNATURE	E. CORRECTED BY	F. INSPECTED BY	G. SUPERVISOR
CONFIGURATION	☐ YES	☑ NO	D. Malone AZ3		D. Penrod ASI	J. D. McCoy ASC
LOG	☑ YES	☐ NO				
ACCESS RECORD	☐ YES	☑ NO				

30. REPAIR CYCLE DATA

	DATE		DATE
1. REMOVED		5. TO AWP	
2. RECEIVED MATL. CONTROL		6. OFF AWP	
3. WORK STARTED		7. TO AWP	
4. COMPLETED		8. OFF AWP	
RFI ☐ B COND ☐ R/S ☐		9.	
		0.	
H. PCN	PRIORITY	DATE DUE IN	OUT

40. FAILED MATERIAL

.1 ACT TKN	.2 MAL	.3 QTY	.4 MFGR	.5 PART NUMBER/REF. SYMBOL

J. ACCUMULATED HOURS

NAME/SHIFT	DATE	MAN-HOURS	EMT
TOTAL			

K. REQUIRED MATERIAL

REQ. NO.	MFGR	PART NUMBER	QTY	PRI	DATE/TIME ORD	DATE/TIME REC	AWP

AS.691

Figure 10-35.—Completed Maintenance Action Form (MAF) for Calendar inspection—control copy.

Blocks 14 and 15 - Manhours and Elapsed Maintenance Time. The total manhours and elapsed maintenance time expended by personnel from the specified work center are entered in these blocks.

Block B - Discrepancy. A description of that part of the inspection to be accomplished by the indicated work center is entered here. Example: Complete cards 5 through 8.

Block C - Corrective Action. A description of the action taken is entered here. Example: Completed cards 5 through 8.

Block E - Corrected By. The worker or crew leader who performs or supervises the indicated part of the inspection signs his name and enters his rate in this block.

Block F - Inspected By. The Quality Assurance or Collateral Duty Inspector who inspects the job for proper standards signs his name and enters his rate in this block.

Block G - Supervisor. The supervisor of the indicated work center, or his assistant, signs his name and enters his rate in this block to indicate that screening and other appropriate action has been performed.

The documenting procedure described in the preceding paragraphs covers the look phase of a Calendar inspection. The look phase is that portion of an inspection that includes the basic requirements outlined by the MRC's. This excludes the repair of discrepancies that cannot be completed within the time allotted on the MRC's. Each discrepancy found during a Calendar inspection is documented on a separate MAF. If the discrepancy can be fixed in place or does not result in the generation of a repairable item, the maintenance action may be documented on a single copy MAF. If the discrepancy requires the processing of a repairable component, a multiple-copy MAF must be initiated.

HOISTING EQUIPMENT

There are many different types of hoisting and lifting equipment used to support the operation of aircraft. In addition, hoisting equipment is frequently used in the maintenance of support equipment. This equipment includes jacks, chain hoists, cranes, forklifts, weapons loaders, etc. The operation and maintenance of many of these items are covered elsewhere in this training course. For example, the hydraulic maintenance of forklifts, jacks, and weapons loaders is covered in chapter 14, and the maintenance and operation of chain hoists and block and tackle are covered in chapter 11. Inspection and load testing of hoisting equipment are covered in this section.

Obviously, the inspection of hoisting and lifting equipment is very important for the safety of personnel, materials, and equipment. Management of Transportation Equipment, NavDocks P-300, the applicable Servicing Instructions for the specific item of equipment, and local command instructions should be consulted for the intervals and procedures for inspection and load testing of hoisting and lifting equipment.

The following is a list of structural and mechanical details that must be inspected at regular intervals. The list pertains to hoisting equipment in general; therefore, all items may not apply to each type of equipment.

1. Bent, cracked, or excessively corroded members.
2. Cracked or excessively corroded welds.
3. Loose rivets or bolts.
4. Corroded or broken counterweights.
5. Condition of counterweights.
6. Outriggers, for lost pieces and ease of operation.
7. Bent or cracked hooks.
8. Roughly worn sheaves.
9. Stuck bearings or bushings.
10. Excessively worn parts, such as pins, bushings, shafts, gears, and worms.
11. Adjustment of equalizers.
12. Brake and clutch linings and corresponding metal friction surfaces.
13. Brake pawls and ratchets.
14. Jaw clutch wear.
15. Moving parts of control mechanisms.
16. Rigid and flexible lines, tanks, valves, drains, filters, etc., of air or hydraulic systems.
17. All wire rope for broken strands and security of attaching fittings.
18. All adjustments and all motions for proper operation.

As previously mentioned, hoisting and lifting equipment must be load tested at regular intervals and after major repairs. A load test normally consists of lifting or hoisting a static weight with the equipment being tested. The weight is usually a small percentage over the rated weight capacity of the equipment being tested. All defective hoisting or lifting equipment must be placed out of service until repaired.

CHAPTER 11
CHASSIS MAINTENANCE

The chassis is the undercarriage of the vehicle to which are attached the units and assemblies which make it operational. These include the axles, springs, shock absorbers, steering mechanisms, wheels, and brakes. These units are mounted on the frame, which must be strong enough to support the weight and rated load of the vehicle without distortion. The frame must be rigid enough to keep the units of the vehicle in proper alignment and to protect them against the stresses and strains of road shocks. The term chassis could properly be construed to mean all of the major operating parts of a vehicle, including the engine. For the purpose of this chapter, however, reference will be made only to the frame, axles, springs and shock absorbers, wheels, and tires and tubes.

Some items of equipment used to move and service aircraft have no springs or shock absorbers. Their running gear, power train, and engines are bolted directly to the frame. However, the ASH is required to service and maintain these components. Therefore, a passenger car chassis is used as a typical chassis in this chapter in order to give a description of all the components with which the ASH will come in contact.

In order to service, maintain, and make repairs to chassis and frames the ASH must be familiar with equipment such as the block and tackle, chain hoists, and jacks. The first section of this chapter covers this equipment and the remainder of the chapter is devoted to chassis maintenance.

SERVICE EQUIPMENT

Due to the location of the chassis components of ground support equipment, hoists or jacks are required for almost all service requirements. The following paragraphs cover some of the service equipment that is required in the chassis section of the ground support equipment work center.

BLOCK AND TACKLE

A block consists of one or more sheaves fitted in a wood or metal frame supported by a hook or shackle inserted in the strap of the block. A tackle is an assembly of blocks and lines uses to gain a mechanical advantage in lifting or pulling.

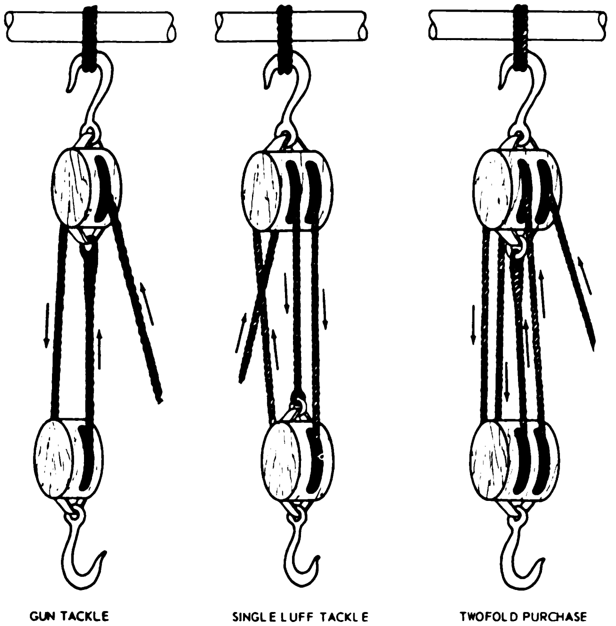
The mechanical advantage of a tackle is the term applied to the relationship between the load being lifted and the power required to lift that load. If a load of 10 pounds requires 10 pounds of power to lift it, the mechanical advantage is one. However, if a load of 50 pounds requires only 10 pounds to lift it, then the mechanical advantage is 5, or 5 units of weight are lifted for each unit of power applied. Therefore, blocks and lines in various combinations can be used in lifting and moving heavy loads. (See fig. 11-1.)

Whenever hoisting or moving heavy objects, using blocks and tackle, keep SAFETY uppermost in mind. This includes safety for men and material.

Always check the condition of blocks and lines before using them to hoist or move heavy equipment. Make sure the blocks are properly lubricated and the line is not frayed or broken. Never leave a load suspended by a block and tackle. If a job must be interrupted while a load is suspended by a block and tackle, either brace the load with suitable equipment or lower the load to the deck.

CHAIN HOISTS

Chain hoists, or chain falls as they are often called, provide a convenient and efficient method for hoisting loads by hand. Chief advantages of chain hoists are that one man can raise a load of several tons, and the load can remain stationary without being secured. The slow lifting travel of a chain hoise permits small movements, accurate adjustments of height, and gentle handling of loads. For these reasons they are particularly useful in hoisting vehicles



AB.251
Figure 11-1.—Common tackles.

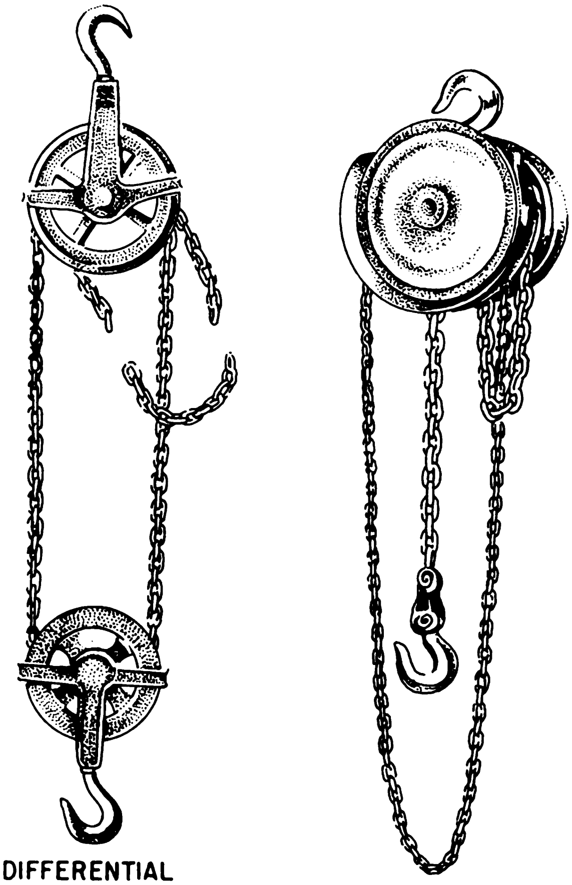
for chassis component repairs and removal and replacement. Two of the most common types used for vertical hoisting operations are the spur gear hoist and the differential chain hoist. (See fig. 11-2.)

The spur gear hoist is best suited for ordinary operations that require frequent use of a hoist and where a minimum number of men are available to operate it. The spur gear hoist is about 85 percent efficient. In other words, about 85 percent of the energy exerted by the user is converted into useful work for lifting the load. The remaining 15 percent of the energy is spent in overcoming friction in the gears, bearings, and chains.

The differential chain hoist is suitable for light loads and where only occasional use of the hoist is involved. This hoist is only about 35 percent efficient.

The mechanical advantages of chain hoists vary from 5 to 250, depending on their rated capacities, which range from 1/2 ton to 40 tons. The load capacity of a chain hoist is stamped on the shell of the upper block.

The lower hook is usually the weakest part in the assembly of a chain hoist. This is intended as a safety measure so that the hook



AB.11
Figure 11-2.—Chain hoists.

will start to spread open if overloaded. Thus, close observance is necessary to detect any sign of overloading in time to prevent damage.

Before using a chain hoist, inspect it to insure safe operation. A hook that shows signs of spreading or excessive wear should be replaced. If links in the chain are distorted, the chain hoist has probably been overloaded. In any case, make sure the hoist is in good repair before attempting to lift a load. Procedures for testing hoisting equipment are covered in chapter 10.

JACKS

Jacks are used to raise or lower heavy loads short distances. Some jacks are used for

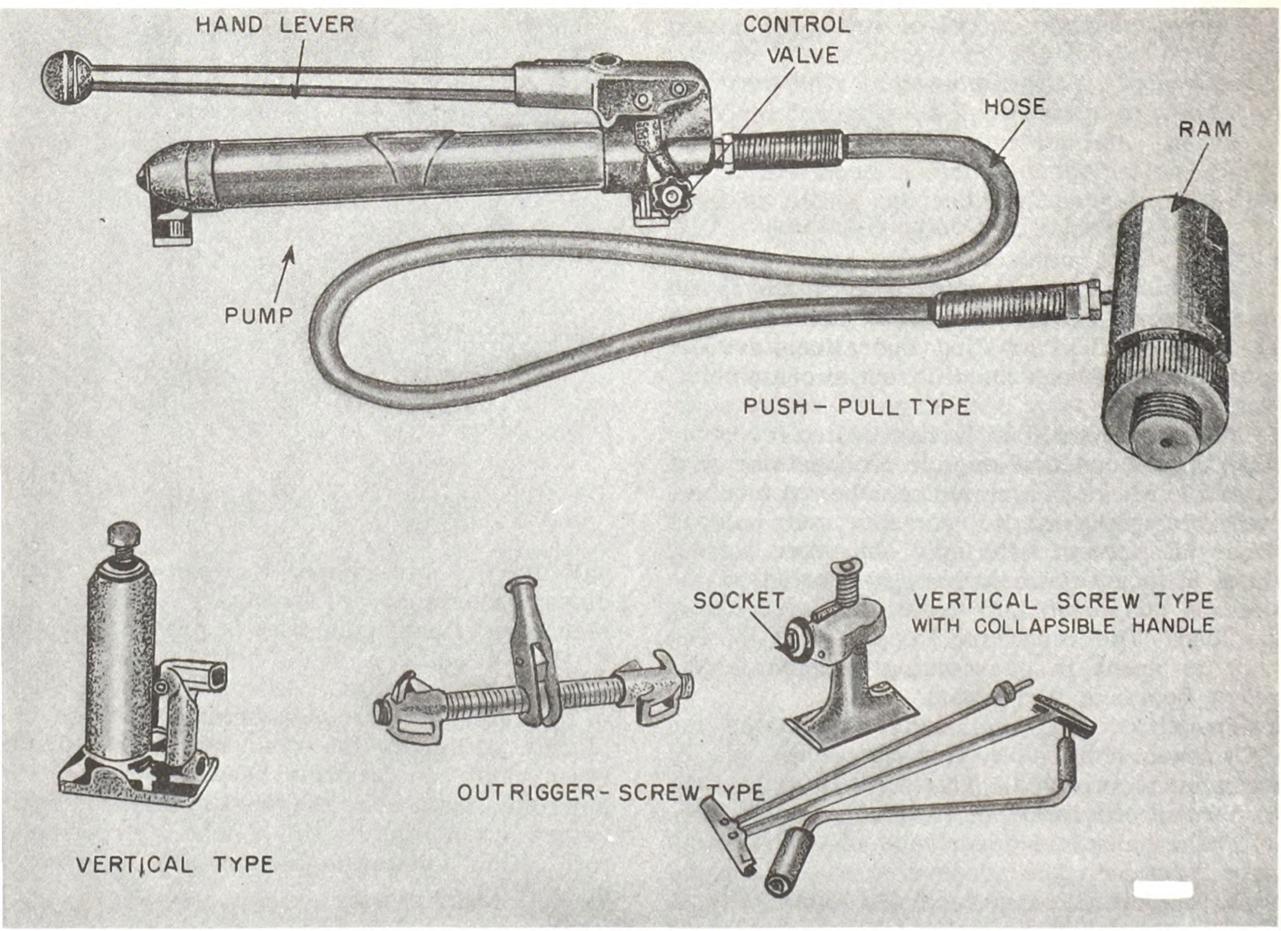
ushing and pulling operations, or for spreading nd clamping.

Jacks are available in capacities from 1 1/2 o 100 tons. Small capacity jacks are generally perated through a rack bar or screw, while hose of large capacity are usually operated ydraulically. (See fig. 11-3.)

The vertical screw jack is operated by hand hrough a collapsible handle which is inserted n a socket. The screw moves up or down, de- ending on the direction of rotation in which the andle is turned. Some of these jacks are quipped with a ratchet for automatic lowering. Aechanical screw jacks come in several capac- ties having different contracted and extended eights. Another type of screw jack is called an outrigger jack. It is equipped with end fittings which permit pulling parts together or pushing them apart.

A vertical hydraulic jack operates through pressure applied to one side of a hydraulic cylinder which moves the jack head. These jacks are automatically lowered or released by releasing the pressure. Vertical hydraulic jacks are available in different capacities from 3 to 100 tons and have different extended heights.

Vertical jacks are used to lift one side or the end of a vehicle to permit removal of chassis components or to effect repairs that would not be possible with the vehicle standing on its wheels. The jack can be used on each side alternately by jacking one side of the vehicle,



AS.692

Figure 11-3.—Jacks.

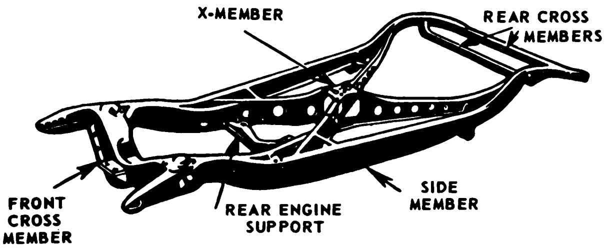
then blocking it and moving the jack to the other side, and continuing this operation until the vehicle has been raised to the desired height. It is essential that the jack be placed on solid ground or on boards to spread the weight so the jack will not give way or tip when being used.

A push-pull hydraulic jack consists of a pump and ram connected by a flexible hose. Jacks of this type are rated at 2-, 7-, 20-, 30-, and 100-ton capacities and have diversified applications. These jacks are furnished with an assortment of attachments that enable the user to perform countless pushing, pulling, lifting, pressing, bending, spreading, and clamping operations. The pump is hand operated. A flexible hydraulic hose allows the operator to operate the ram in any desired position and from a safe distance. The ram can be retracted automatically by turning a single control valve.

When using a jack to raise a vehicle make certain no one is under the vehicle. Keep fingers away from all moving parts. Place blocking or other supports under the vehicle when it is raised to the desired height to prevent it from dropping if the jack fails. Before using a hydraulic jack make sure it is filled with fluid and has no apparent leaks.

FRAME

The frame is designed to support all body and engine parts and is in turn supported by the front and rear wheel springs. The frame is normally made up of specially formed channel or U-shaped members that are riveted or welded together. (See fig. 11-4.)



AS.693
Figure 11-4.—Passenger car frame.

DESCRIPTION

The frame is generally constructed of cold-rolled open-hearth steel and is extremely rigid and strong so that it can withstand the shock blows, twists, vibrations, and other strains to which it is subjected during its service life. The side members or rails are the heaviest parts of the frame. The crossmembers are attached to the side members strongly enough to prevent weaving and twisting of the frame. Angular pieces of metal called gusset plates are riveted or welded at the point where members are joined for added strength.

The number, size, and arrangement of crossmembers depend on the type of vehicle for which the frame is designed. Usually, a front crossmember supports the radiator and front end of the engine as well as adding strength to the frame. The rear crossmembers furnish support for the fuel tanks and rear trunk on passenger cars, and tow bar connections for trucks and tractors. Additional crossmembers or X-members are added to the frame to support the rear of the engine and power train and to secure the rigidity required.

The crossmembers of most small vehicles are designed in either X or K form. The front crossmembers are wider and are constructed of heavier materials than the rear members because they support the engine and the front wheels. The side members are shaped to accommodate the body and support its weight. They narrow toward the front of the vehicle to permit a shorter turning radius and widen under the main part of the body where the body is attached to the frame. The shape of some passenger car frames is designed in boxlike form with straight parallel side members.

Trucks and trailers usually have frames with straight side members to accommodate several designs of bodies and to give the vehicle added strength to withstand heavier loads.

Brackets and hangers are bolted or riveted to the frame to support the shock absorbers, springs, and fenders. These brackets and hangers are usually manufactured from case or pressed steel, depending on the strength required. Spring hangers subject to twisting and running gear stresses are, in most cases, drop forgings.

INSPECTION AND MAINTENANCE

Frames require very little, if any maintenance. Frames that have been bent, twisted, or broken may be repaired if the damage is not too severe. In order to determine if a frame

as been bent, frame alignment can be checked y several methods.

One method of checking the frame for forvard alignment is by using frame gages. In sing this method, frame gages, each having a ight mounted on its center crossbar, are hung rom the vehicle's frame in three different laces. Frame alignment is checked by sighting rom the front of the vehicle toward the rear. f the sights on the center of the gages do not ine up, the frame is out of alignment.

A more complete check of frame alignment an be made by using a plumb bob to transfer o the floor a pattern of the vehicle frame. This peration must be very carefully performed in rder to obtain correct measurements. The loor must be clean and level. Paper can be asted or tacked to the floor if desired. Using he plumb bob, mark on the floor the various rame points between which measurements are o be taken. Then roll the vehicle out of the vay and measure between the points marked on he floor. Prior to checking the alignment of a ehicle by the plumb bob method, the appropriate technical manual must be consulted for he measurements to be taken and the proper rame dimensions.

If the frame is out of line, it is usually pernissible to straighten it, provided the lack of lignment is not too great. The appropriate echnical manual must be consulted prior to ttempting to straighten the frame of a vehicle.

Some vehicle manufacturers recommend that rame members be straightened cold, without he application of heat. It is their contention hat application of heat weakens the frame nembers excessively. Others state that heat nay be applied, provided the temperature of he steel is kept below 1,200°F. Heat above this emperature may seriously weaken the steel.

A torch can be used to apply heat to a frame nember to be straightened. Special tools are isually required. These include heavy I-beams laced alongside the distorted frame member, hains to be attached between the I-beam and he frame member, and jacks to apply straightening pressure.

When frame members have been broken or o badly distorted that they require replacenent, new members can be installed with either ivets or nuts and bolts. The preferred method s the hot-rivet method or heating the rivet efore it is riveted into place.

When the front suspension crossmember as been damaged, it is the usual practice to replace it. This part is manufactured to extremely close tolerances and, if it is once bent, it is practically impossible to restore it to perfect alignment. If it is not in proper alignment, the front wheels cannot be properly aligned, and poor steering control and rapid tire wear will result.

Some of the large permanent work centers may have nonportable frame straightening machines installed. This equipment may be installed in a pit or elevated on a floor with ramps attached for vehicular mounting.

The complete machine includes a number of gages and parts designed so that they can be adapted to the location and nature of the bend or distortion to be corrected. Hydraulic jacks are also furnished as equipment for frame straightening operations.

AXLES

Although axles used on support equipment are of different sizes, shapes, and lengths, they are classified into two distinct categories—driving and nondriving. The driving axle, also known as live axle, transmits power from the transmission directly to the driving wheels of the vehicle. These wheels can be the front, rear, or front and rear wheels. Nondriving axles, also known as dead axles, are mounted to the frame or chassis and remain stationary. This type of axle may run the entire width of the vehicle or may be only a short axle mounted on a faceplate and bolted to the side of the frame or chassis. Some nondriving axles will have wheels mounted directly on the end of the axle (rear wheels of a trailer). Others will have the wheels mounted on steering knuckles, which in turn are mounted on the ends of the axle (front wheels of a trailer). (See fig. 11-5.)

INSPECTION AND MAINTENANCE

Axles require very little maintenance. Nondriving axles may require straightening or replacement due to accidents or rough handling. Whenever a vehicle has a bent or damaged nondriving axle the appropriate technical manual must be consulted for the repair limits and procedures.

If trouble develops with a driving axle the only solution is to replace the axle. Normally the only troubles encountered with driving axles result from defective wheel bearings or a complete break of the axle. Driving axles are

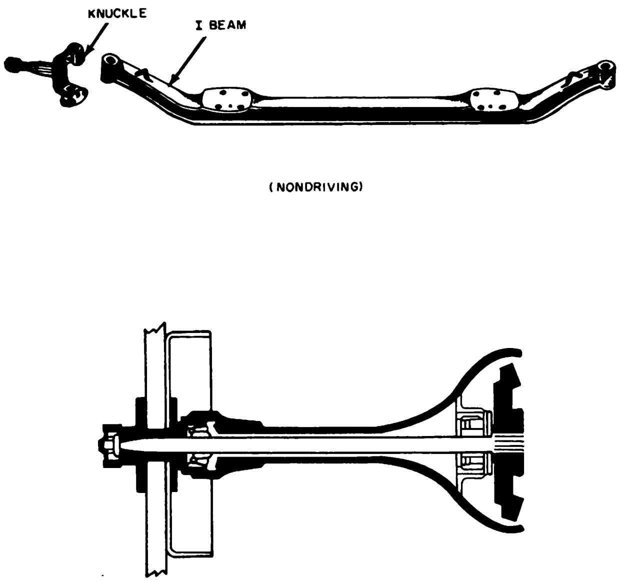


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Figure 11-5.—Axles.

encased in a housing and are therefore isolated from the outside elements.

Normally, replacement of driving axles requires removal of several parts from the axle housing. When these parts are removed they should be handled carefully and inspected thoroughly. Any faulty or suspected parts should be replaced. Care must be taken to prevent damage to the brakes, lines, and the axle oil seals. Never strike the end of an axle shaft to loosen it as this may damage the bearings or differential.

SPRINGS AND SHOCK ABSORBERS

The vehicle wheels are suspended on springs that support the weight of the vehicle. The springs absorb road shock as the wheels encounter holes or bumps and prevent, to a large extent, any consequent jarring action or up-and-down motion from being carried through the frame and body. Springs alone cannot provide a satisfactorily smooth ride. Therefore, an additional device, called a shock absorber, is used with each spring. Shock absorbers are designed to prevent spring oscillations and allow smoother, safer operation of the vehicle. Although shock absorbers and springs are covered together in the following paragraphs not all types of ground support equipment have shock absorbers and springs. Some equipment will have springs, some will have shock absorbers, and some equipment will have both or neither one.

TYPES

The types of springs the ASH will be required to inspect, service, and replace are the coil type, leaf type, torsion bar, and, on some of the late model vehicles, air suspension. (See fig. 11-6.)

The coil spring is a heavy coil. The weight of the frame and body puts an initial compression on the spring. The spring will further compress when the wheel passes over an obstruction in the road. It will expand if the wheel encounters a hole in the road.

The leaf spring is made up of a series of flat plates, or leaves, of graduated lengths, one on top of another. The spring assembly acts as a flexible beam and is usually fastened at the two ends to the vehicle frame and at the center to the wheel axle. Some vehicles use only one leaf spring at the rear and one at the front, each spring supporting two wheels. With this design, the center of the spring is attached to the frame and each end of the spring supports a wheel. The action is similar on all leaf springs. When the wheel encounters a bump, the spring bends upward to absorb the shock. When the wheel drops into a hole, the spring bends downward. Thus, the leaf spring does the same job as the coil spring in a vehicle.

The ends of a leaf spring are connected to the frame or axle with spring hangers and shackles. Spring hangers are fittings to which the spring ends are attached. A bolt or pin passes through the bushing in the spring eye and is secured to the spring hanger on the frame. The bushing and shackle bolt or pin, therefore, provide the bearing surface which supports the load on the spring.

The spring bushings may be made of bronze or rubber. They may be pressed or screwed into the spring eye, depending on the design. The steel bolts or pins that pass through the bushing are also either plain or threaded. Threaded bushing and shackle bolts offer a greater bearing surface and are replaced more easily when they become worn.

When a leaf spring is compressed, it must straighten out or break. Therefore, spring shackles are required at one or both ends of

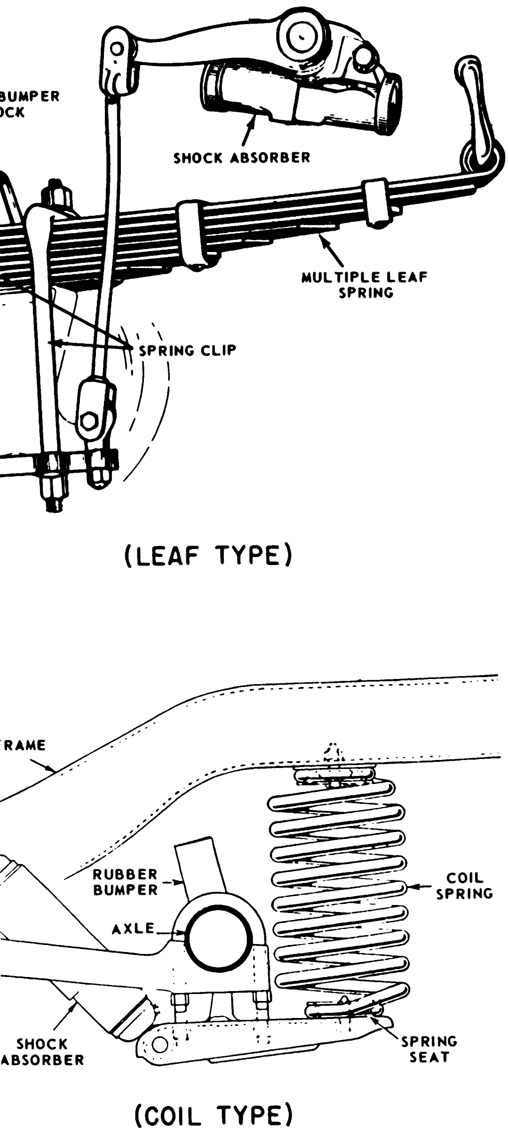

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Figure 11-6.—Springs.

ng. Spring shackles provide a swinging and allow the spring to straighten out ompressed. One shackle is used in he front or rear support of springs in- lengthwise. Two shackles are used in ng springs installed crosswise.

e torsion bar suspension, the springing s produced by torsion, or a twisting n long bars. There are many variations of the torsion bar suspension system; however, they all work on the same principle. One of the most popular systems employs a separate torsion bar for each wheel. On these, the wheel end has a lever attached in such a way as to support the wheel. The other end of the torsion bar is fastened rigidly to the vehicle frame. The bar is then twisted more or less in accordance to the loading at the wheel.

In air suspension, the four conventional springs are replaced by four air bags or air-spring assemblies. Each air-spring assembly is a flexible bag enclosed in a metal dome or girdle. The bag is filled with compressed air which supports the weight of the vehicle. When a wheel encounters a bump in the road, the air is further compressed and absorbs the shock.

Shock absorbers used on ground support equipment are classified as single acting, double acting, and direct acting or telescoping. (See fig. 11-7.) Single acting shock absorbers check the spring rebound, while the double acting shock absorber checks spring compression as well as rebound. One variation of the single acting shock absorber is shown in figure 11-8. These are individual shock absorbing wheel mount assemblies and are bolted directly to the chassis. Four of these assemblies are used on the model P5R15GA air compressor. Direct acting or telescoping shock absorbers are found on front as well as rear suspension systems and can be mounted in a vertical or slanted position.

INSPECTION AND MAINTENANCE

Breakage of springs can result from excessive overloading, loose U-bolts which cause breakage near the center bolt, loose center bolt, improperly operating shock absorber, and tight spring shackle. Whenever a broken spring is to be replaced the cause must be determined and corrective action taken to prevent the new spring from breaking.

Springs will sag from habitual overloading. Defective shock absorbers may tend to restrict spring action and thus make them appear to sag more than normal.

The noises produced by spring or shock absorber difficulties will usually be either rattles or squeaks. Rattling noises can be produced by looseness of such parts as spring U-bolts, metal spring cover, rebound clips, spring shackles, or shock absorber linkages and springs. These can generally be found by a

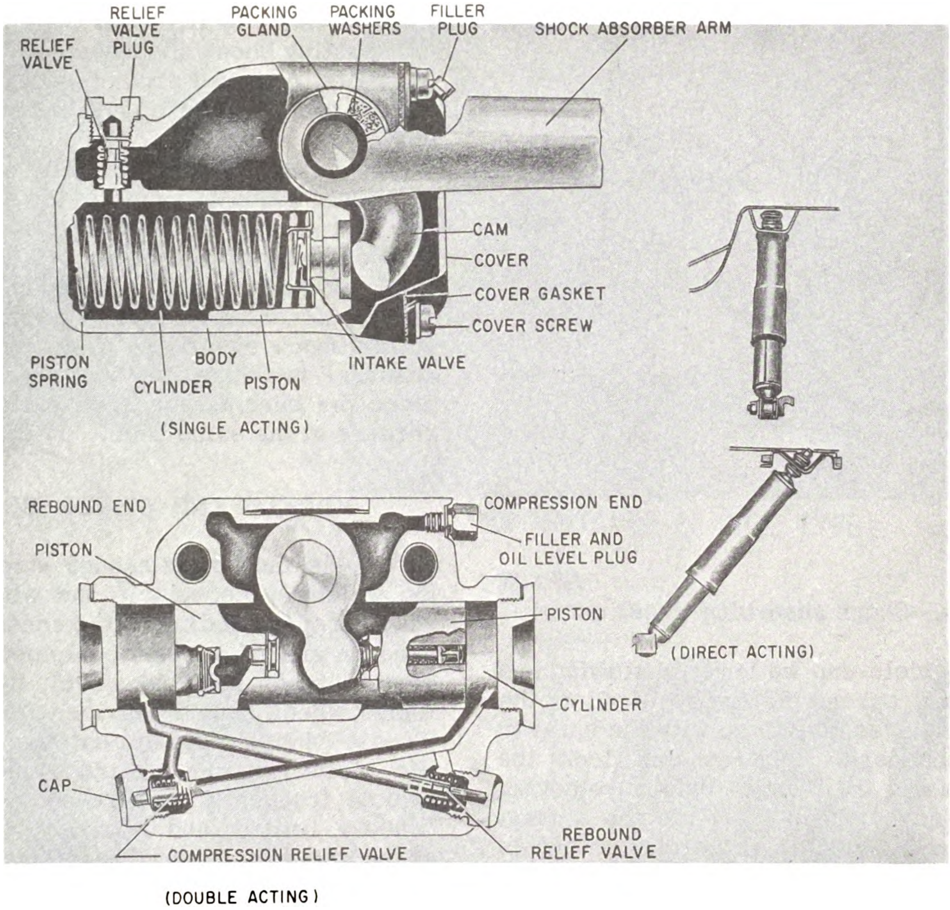

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Figure 11-7.—Shock absorbers.

careful examination of the various suspension parts. Spring squeaks can result from lack of lubrication in the spring shackles, at spring bushings (on the type requiring lubrication), or in the spring itself (leaf type requiring lubrication). Shock absorber squeak could result from tight or dry bushings and worn or defective attaching grommets.

To replace a spring, first make sure the vehicle is properly blocked on a level surface. Raise and support the frame on strong hoisting equipment or jacks to remove all weight from the springs. Remove and disconnect the necessary parts from the removal path. (Some vehicles require the wheel to be removed and others require the shock absorber to be disconnected to relieve the tension at the shackle bolts or pins.)

Remove the U-bolts fastening the spring at the center before disconnecting the spring from the shackles or spring hangers. Keep all removed parts together (they should be cleaned and inspected prior to reinstallation). Do not attempt to lift the spring out of position while lying down.

Before replacing a spring, check the fit of the pins in the spring bushings and make sure the grease channels are open. Keep in mind that the front and rear springs are usually different.

A new spring is rather stiff. Nevertheless, when the spring is installed, it has to span the distance from one spring hanger to the other. To make this job easier, fasten the spring at the center before connecting the ends. The

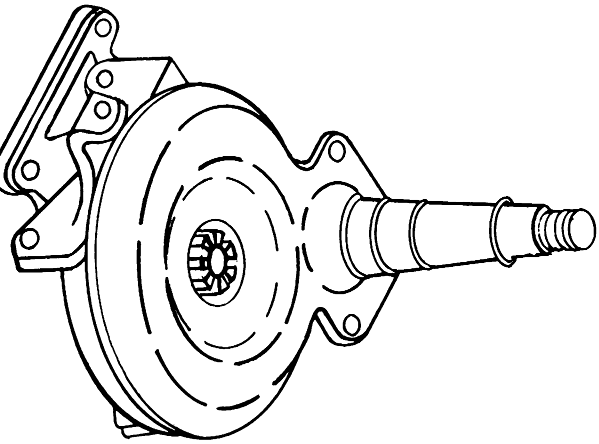

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Figure 11-8.—Shock absorbing wheel mount.

ody of the vehicle can be lowered slowly, and his weight will spread the spring to allow the ıoles in spring eyes to line up with the holes in he spring hangers. Tighten and lock the hackle bolts and the U-bolts before removing he hoist or jacks. Then lubricate the spring.

Springs are lubricated at regular intervals n accordance with the applicable maintenance nanual or the appropriate Maintenance Requirenents Cards. When springs are lubricated, pecial attention must be given the shackles. Grease must get through the grease fitting to oth sides of the shackles. Grease on the outide of the shackle is wasted; it must be forced etween the shackle bolts and spring bushings o reduce friction.

Use a bar, or jack up the body if necessary, o loosen the bearing surface. If the grease un forces grease out of the fitting instead of hrough the shackle bolt, the grease fitting must e replaced. It is often necessary to use a vire to remove caked grease from the openings.

Both surfaces of spring leaves are lubricated vith a film of grease before the spring is asembled. It is a good practice to occasionally pray leaf springs. Lubricating oil sprayed on prings will prevent squeaking at the ends of he spring leaves when the springs are flexed.

Shock absorbers depend on fluid and valve ction for proper control. The direct acting or elescoping shock absorber cannot be refilled. t must be replaced if it becomes defective. Shock absorbers should be replaced in sets, front or rear, to maintain body stability. The lever acting shock absorbers are refilled without being removed from the vehicle. A filler plug is provided in the shock absorber for fluid servicing. (See fig. 11-7.) The fluid level should be checked periodically and the necessary fluid added to maintain the specified level. Any dirt around the filler plug must be removed before removing the plug.

Shock absorbers should never be mismated; that is, never pair a single acting with a double acting shock absorber. When replacing shock absorber bushings, the best practice is to replace the bushings on each pair of shock absorbers at the same time.

WHEELS AND WHEEL BEARING

Wheels must have enough strength to carry the weight of the vehicle and withstand a wide range of speed and operating conditions. Wheels used on ground support equipment are of three general types—the disk wheel, the demountable flange wheel, and the divided (or split) wheel. Wheels should operate satisfactorily for the life of the vehicle but are removed from the vehicle frequently for tire change, inspections (wheels, brakes, and bearings), and lubrication of the wheel bearings. The following paragraphs describe the types of wheels and wheel bearings, illustrate the various parts of a typical wheel assembly, and describe the procedures for removing and installing wheels.

TYPES

Figure 11-9 illustrates the three general types of wheels used on ground support equipment. The disk wheel is used only with lighter tires that have a soft enough tire bead to flex into a slight elliptical or egg shape form for removal and installation over the rim. The flange type is required where the tire bead is too stiff to be flexed over the rim. Split wheels are used mostly with small tires, such as those used on tractors, trailers, and servicing equipment.

Wheel bearings are adjustable, tapered, roller bearing type. The wheel nut makes the correct bearing adjustment and keeps the wheel on the hub. A cotter pin keeps the nut from coming loose. Bearings used in drive axle installations are mounted within the axle housing.

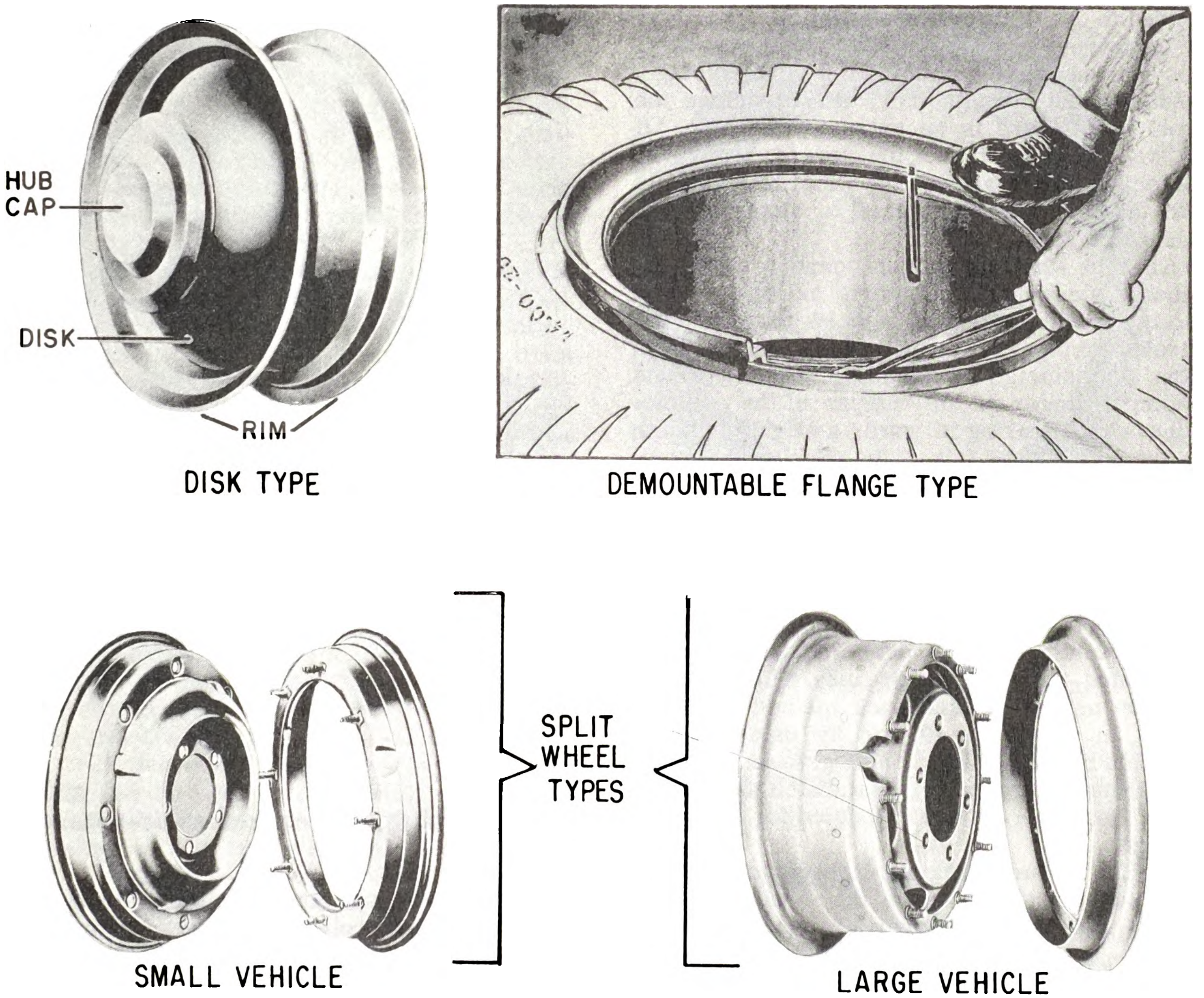

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Figure 11-9.—Wheels.

INSPECTION AND MAINTENANCE

Wheels are manufactured to close limits and usually are fairly well balanced at the factory. However, since a vehicle is likely to be driven over holes, ruts, grooves, and bumps in a roadway, or against curbs, the wheels may become bent or tires may wear unevenly, so that the whole assembly may become unbalanced. Wheels that are not true—that is, those that wobble or shimmy, and tires that are out of balance—tend to promote unsatisfactory vehicle performance.

To give maximum service, any wheel must run true in its plane of rotation at any normal speed. A wheel that is sprung out of line, because of a sudden jolt due to a road hazard or an impact during an accident, will have the supported weight of the vehicle shifted about the spin axis of the wheel. The resulting unbalanced forces will cause the wheel to wobble and the vehicle to shimmy. Extreme wheel wobble may be detected by watching a wheel as it rotates on a vehicle. However, the wheel wobble may be so slight that it is impossible to

etect visually. In this case, a shimmy detector ; used to check the wheel operation.

To correct a sprung or bent wheel condition, is necessary to straighten the wheel, using a pecial wheel straightener, or to replace the heel when there is an extreme condition. If ne wheel wobble is not too severe, it may be orrected by the addition of small lead weights nto the rim at exact places to offset the unalanced effect.

Correct wheel alignment cannot be mainained if steering system parts are worn or out f adjustment. Included in these parts are the heel bearings. A worn wheel bearing can ften be detected by spinning the wheel and lacing a finger on the bumper of the vehicle. the wheel bearing is worn, a slight vibration r grinding may be felt as the wheel is spinning.

The front or nondriving wheel bearings are emoved, cleaned, and repacked, periodically accordance with existing instructions. When heel bearings are to be repacked they must irst be cleaned with an approved drycleaning olvent. After the wheel bearings are cleaned nd inspected (in that order) they are repacked sing high-temperature grease. This may be one by using the hand pack method as illusrated in figure 11-10, or by using an airperated bearing packer. Felt grease retainers re cleaned or replaced if saturated with lubriant. Bearing cups are inspected for wear and amage.

NOTE: Insure bearings are completely dry rior to packing with lubricant. Water or conensation will cause bearings to rust.

TIRES AND TUBES

Most vehicles with wheels use pneumatic ires which are made of natural or synthetic ubber. They are either tube or tubeless. The unctions of the tire are to place a cushion beween road bumps or irregularities and the heels, and to provide a frictional contact beween the road and the wheels. The following aragraphs cover tire and tube construction nd identification. Also covered are inspection, naintenance, and stowage of tires and tubes.

TYPES AND IDENTIFICATION

The parts of a tire are the tread, breaker, ushion, plies, and beads, as shown in figure 1-11. The tread is a layer of rubber on the utside circumference of the tire. This gives

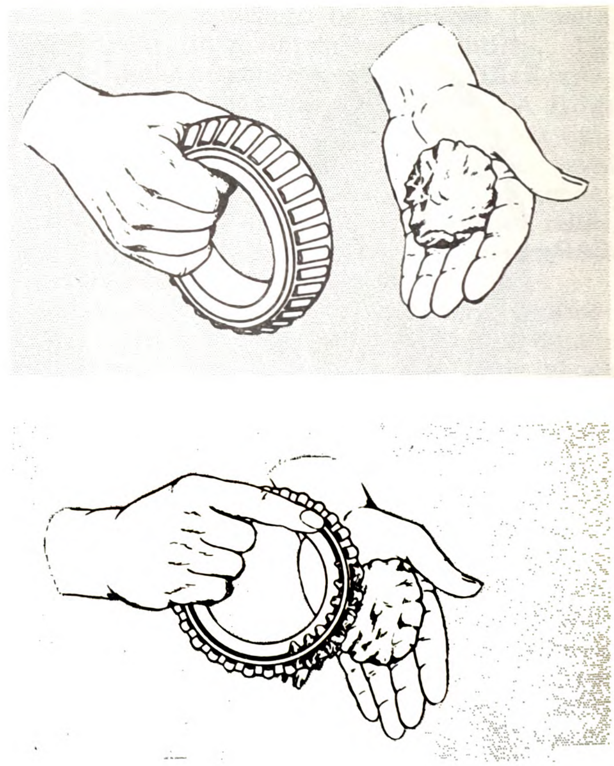

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Figure 11-10.—Hand packing wheel bearings.

the tire a wearing nonskid surface to provide traction, and it protects the inner layers of the tire from cuts and bruises. Beneath the tread is the breaker, a layer of rubber covered cords, which helps to absorb road shock. Underneath the breaker lies the cushion, a layer of soft, heat-resisting rubber which absorbs road shock and binds the breaker to the plies. The plies are layers of rubber covered cords that give the tire strength to resist internal pressures and support heavy loads.

NOTE: The strength of a tire is expressed in ply rating, based on the number of plies of nylon or rayon materials used in its construction. Formerly, tires were constructed only from rayon materials impregnated with rubber. When a tire was constructed with 6 plies, it was called a 6-ply tire. However, with the advent of a newer and stronger ply material, such as nylon, tire strength could not be determined from the number of plies alone. A tire fabricated from 6 plies of nylon could carry greater

loads than one fabricated from 6 plies of rayon. Thus, it became necessary to know the ply material as well as the number of plies. This situation created the need for a system of marking tires which would incorporate a positive indication of strength regardless of the tire construction. Accordingly, marking tires with the actual number of plies has been discontinued on most tire production, having been replaced by ply rating.

Ply rating indicates the actual strength and is based on the strength factor equivalent to a given number of plies. Since nylon has better strength characteristics than rayon, nylon tires are given an extra ply rating. For example, a 10-ply nylon tire is given a 12-ply rating, the same as if it were built of 12 plies of standard rayon construction. The ply rating of tires found on support equipment will vary from 4 for small vehicles to 10 for the heavier equipment.

The bead is that portion of the tire which assumes anchoring of the tire to the rim. The bead consists of strands of high-carbon steel wire embedded in rubber and wrapped with fabric. The rubber helps to tie the bead into position on the tire, and the fabric insulates the wire from the inner core layers.

The illustration in figure 11-11 is of a tube type tire; that is, it requires a rubber inner tube for the tire to be complete. A tubeless tire is similar in appearance and has the word "tubeless" on the tire sidewall. It combines the functions of the tire and the inner tube and has its valve fastened to the wheel rim. A layer of cured rubber compound is vulcanized to the cord plies within the tire and extends from bead to bead to form an airtight chamber. The exterior surfaces of tubeless tire beads have a series of concentric ridges which contact the rim flanges and form a seal to prevent loss of air. The air pressure used in tires of ground support equipment ranges from 22 psi to 100 psi depending on the size of the tire and the function of the vehicle.

Tire sizes are marked on the side of the tire. A tire might be marked 7.00 x 13, for example. The 7.00 indicates the tire is 7 inches wide when it is properly inflated and without a load. The 13 indicates that the tire fits a 13-inch wheel.

Inner tubes are manufactured from three types of rubber, one natural and two synthetic. Today the most common tube material is butyl, a synthetic rubber. A butyl tube can be identified by a blue stripe around the sidewall of

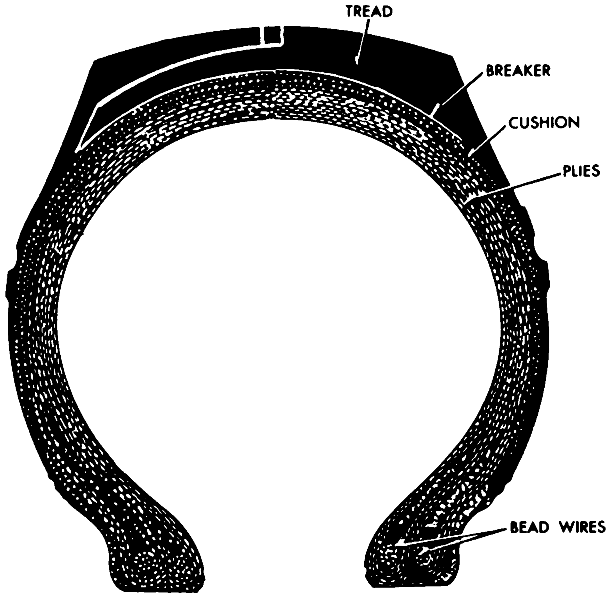

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Figure 11-11.—Construction of a tire.

the tube. The other synthetic rubber (GR-S) has a red stripe. Natural rubber tubes have no stripe.

CHANGING AND MOUNTING

During changing and mounting of tires, safety is paramount. The removal and replacement of tires is not difficult on smaller vehicles, but on large, heavy duty applications special tools are required to remove and handle them. Therefore, the ASH must be familiar with the manufacturer's recommended procedures and safety precautions before attempting to dismount a tire. Air must be released from the tire or tube as a first step in tire removal. (On support equipment using split wheels the air must be released from the tire or tube prior to removing the wheel from the vehicle.)

Tires mounted on a disk wheel can be removed from the wheel by using a tire tool or flat stock. After the air is released from the tire or tube, one part of the bead can be pried over the rim flange (starting near the valve stem). Care must be exercised to avoid damaging the tire bead or inner tube. After the bead is started over the wheel flange with the

:ool, the remainder of the bead can be worked out over the flange with the hands. The other bead of the tire is removed over the same side of the rim flange in a similar manner.

NOTE: On tubeless tires, do not use tire irons to force the beads away from the flanges; this could damage the rim seals on the beads and cause an air leak. Special tools are available to break the tubeless tire beads away from the wheel flanges and must be used.

Prior to mounting a tire and tube, inflate the tube until it is barely rounded and put it in the tire. The inside and outside of the tire bead may be coated with talcum powder or a vegetable oil soft soap to facilitate installation of the tire. In mounting the tire on the rim, install one bead first, following with the second. Pressing down the sidewall of the tire will make it easier to slip the second bead over the wheel flange. After the tire is in place, make sure the beads are up on the bead seats in the rim and that they are uniformly seated all around the rim.

Inflate the tube, making sure that it is properly centered in the tire and that the valve stem is in the center of the rim valve stem hole. Deflate, then reinflate the tube; this assures good alignment of the tire, tube, and rim.

Before installing tubeless tires the rim must be examined carefully and all rust and foreign matter must be cleaned from the rim. If the rim has any dents in it, they must be straightened out prior to the tire installation to insure an airtight fit. Make sure the valve is seated tightly in the rim.

To mount the tire, install the two beads over the rim in the same way as for the tube type tire. Coating the beads and wheel flange with talcum powder or vegetable oil soft soap will make the installation procedure easier. After the tire is mounted on the rim, apply a blast of air to the valve. The valve core should be removed since this will allow the air to enter more freely. The blast of air should force the tire beads outward and into contact with the bead seats on the rim. If the beads do not set, the tire will not hold the air, then the beads must be spread by constricting the tread centerline. This can be done by using a tire mounting band, which is furnished with the large type tire mounting equipment. If a mounting band is not available, the tire can be spread by making a simple tourniquet from available line. As soon as the bead sets, the tire will inflate normally. Remove the band or tourniquet, replace the valve core, and inflate to the recommended pressure.

When removing or mounting tires on split or demountable flange wheels the applicable technical instructions must be consulted and followed to prevent damage to the tires, tubes, and wheels. Also, the safety instructions must be followed at all times. Some of the safety precautions are covered in the following paragraph.

Tires on wheels equipped with lockrings must be inflated in a safety cage when removed from the vehicle. Tires on split wheels must be deflated before removing the wheel from the vehicle and inflated after installing the wheel on the vehicle. All bolts on a split wheel must be installed and tightly secured before the tire is inflated.

As can be seen by the foregoing, although tire mounting and demounting appears to be a simple operation it can be dangerous. Therefore, all safety precautions must be followed at all times.

NOTE: Considerable damage to jet aircraft from FOD (foreign object damage) has been contributed to ground support equipment. For example, one major station noted that tires replacing original equipment were close tread (automobile) type. These tires have an affinity for picking up pebbles, bolts, and nuts when transiting parking lots and other areas adjacent to runways, taxiways, ramps, and hangar aprons. When these tires reach the hard, smooth surfaces of aircraft operating areas, these objects dislodge, endangering safe jet aircraft operation. By making the switch back to open tread (tractor) type tires the station noted a substantial decrease in FOD. Whenever an original tire is to be replaced on ground support equipment, MIL-T-12459C, Military Specification, Tire, Pneumatic, for Military Ground Vehicles, should be consulted prior to installing a replacement tire.

INSPECTION AND MAINTENANCE

Periodic tire inspections are required so that small damages can be detected and repaired before they develop into major defects. There are certain types of damage and wear that can be found by examining the outside of the tire. Thus, abnormal wear, which indicates certain abnormal conditions can be easily seen. This abnormal wear is an indication that the

steering, suspension, or brake system requires service. The effects of overinflation or underinflation on tire treads are also obvious. Less obvious are the internal damages from rim bruises or fabric breaks. Sometimes a tire can be bruised badly enough for fabric to break and yet there will be little indication of the trouble on the outside of the tire. Therefore, the only way to give a tire a thorough inspection is to remove it from the wheel rim so it can be examined inside and out.

Removing the tire from the wheel rim also permits inspection of the tube. Tubes give very little trouble if they are installed correctly. However, careless installation of a tube may give trouble. For example, if the tire rim is rusty or if the tire bead (at the rim) is rough, the tube may chafe through. All rust and rough areas must be sanded off. Dirt in the tire casing will also cause chafing of the tube.

A number of repairs can be made on tires and tubes, ranging from the patching of nail holes, punctures, or cuts to vulcanizing new tread material to the tire casing. This latter operation is known as recapping, since a new cap, or tread, is placed on the tire. Recapping is accomplished by a commercial contractor. Repair procedures vary according to whether the tire is or is not of the tubeless type.

Leaks in tubes may be located by inflating the tube (after it is out of the tire) and then submerging the tube in water. Air bubbles will appear from punctures or holes. Small punctures can be repaired by use of a vulcanizing kit. This consist of a patch with a metal back containing fuel. First, the tube must be cleaned around the injury (by buffing or with solvent). Then remove the protective cover from the patch, clamp it on, and light the fuel. When the patch cools, the tube is ready for use.

Small punctures or cuts can also be repaired with a regular tube-vulcanizing hot plate. Larger tube injuries can be repaired only with a hot plate. The hot plate provides the proper curing or vulcanizing temperature (approximately 300°F). To repair a larger injury to a tube, trim the injured edges away so the hole does not have sharp cuts or jagged edges. Then buff the edge of the opening to a 45-degree angle and roughen the area about an inch around the opening. If the injury must be backed (on the inside of the tube), prepare a patch and apply it to the inside of the tube. Then fill the hole with tube gum and vulcanize it on the hot plate.

NOTE: The cold patch is not generally recommended for tube repair because it is not considered as safe a repair as the vulcanized or hot patch. With the cold patch, rubber cement is applied to the tube and allowed to dry until tacky. A second coat is applied, and then the patch is applied.

Tube type tire repairs are authorized but are closely monitored. Therefore, prior to attempting repairs to tube type tires the applicable technical instructions must be consulted.

The tubeless tire must be examined carefully for puncturing objects prior to attempting to repair the tire. This type of tire may carry nails or other puncturing objects for considerable mileage without leaking. Puncturing objects must be removed. Leaks may be located in the same manner as for the inner tube.

There are a number of ways to repair punctures in tubeless tires. The methods described here are for small punctures.

One type of repair that can be made to a tubeless tire is the pressure gun repair. If the puncture is less than 3/32 inch in size, it can be repaired with a pressure gun. If the tire is still on the vehicle, jack up the vehicle to take all weight off the tire. Reduce the tire pressure to about 10 pounds, remove the puncturing object (if still in place), and clean out the hole in the tire with a rasp. Remove the plug from the gun nozzle and turn the handle until the sealing dough appears. Wipe off the nozzle to make sure only fresh dough will be used. Center the nozzle over the puncture and press it firmly against the tire. Turn the screw handle two full turns (or follow the manufacturer's instructions) to fill the hole. Allow the tire to stand 20 minutes before reinflating it.

The rubber plug method of tire repair can be used for injuries up to about 1/4 inch in size. First remove the puncturing object. Then use a rasp to clean out the hole. Apply rubber cement to the inside of the hole by coating the needle used to insert the plug. Work the needle around inside the puncture until the inside of the hole is well coated. The diameter of the plug selected must be twice the diameter of the hole. Roll the small end of the plug into the eye of the needle. The end of a 1/4-inch plug should be pulled through the eye of the needle approximately 3/8 inch, and the small end of larger plugs should be pulled through almost to the shoulder of the plug. Dip the plug and needle into the rubber cement and insert them into the hole. Push the needle in until the

ort end of the plug snaps through the tire. move the needle by pulling it straight out. im the plug 1/8 inch above the tread surface d check for leakage. If no leakage occurs, tire is ready for service after it is inflated.

NOTE: The rubber plug method of tire reir can be accomplished with the tire mounted the vehicle or removed from the vehicle. If repairs are to be made with the tire inılled on the vehicle the same preliminary ocedures apply as for the pressure gun reir method.

The hot patch repairs to tubeless tires is larger holes and requires removal of the e from the rim. The patch must be applied the inside of the tire. With the tire removed om the rim, clean out the hole with a rasp. ll the injury from the outside with sealing ugh from the pressure gun. Clean the inside the tire around the injury with an approved lvent and allow it to dry. Roughen the area th a hand buffer or wire brush. Center the t patch over the injury and install the special t patch clamp to hold it in place. Heat the tch by the method required by the manufacrer. (Some are heated by lighting with a atch or flame and others are heated electrilly.) After the patch is cured, remount and late the tire. Check for leakage; if no leake occurs, the tire is ready for service.

ROTATING TIRES

The amount of wear that a tire receives varies according to its location on the vehicle. The right rear tire, for example, wears more than twice as fast as the left front tire. Of the four tires, the right rear tire wears most rapidly, the left rear tire is next, the right front tire is third, and the left front tire wears the least amount of all. To equalize tire wear, it is recommended that tires be rotated every 5,000 miles of operation. Figure 11-12 illustrates the recommended tire rotation plan.

On vehicles having a spare tire, the left front tire should be moved to the left rear, the left rear moved to the right front, the right front to the spare, the spare should be installed on the right rear, and the right rear moved to the left front. On vehicles having no spare, move the front tires to the rear on the same side, and move the rear tires to the opposite front wheels. Tires with directional treads are retained on the same side of the vehicle in order to take full advantage of the tread designs. Therefore, these tires remain on the same side of the vehicle and the rotation consists of swapping places with the front and rear tires.

STORAGE

The life of a tire is directly affected by storage conditions. Tires should be stored

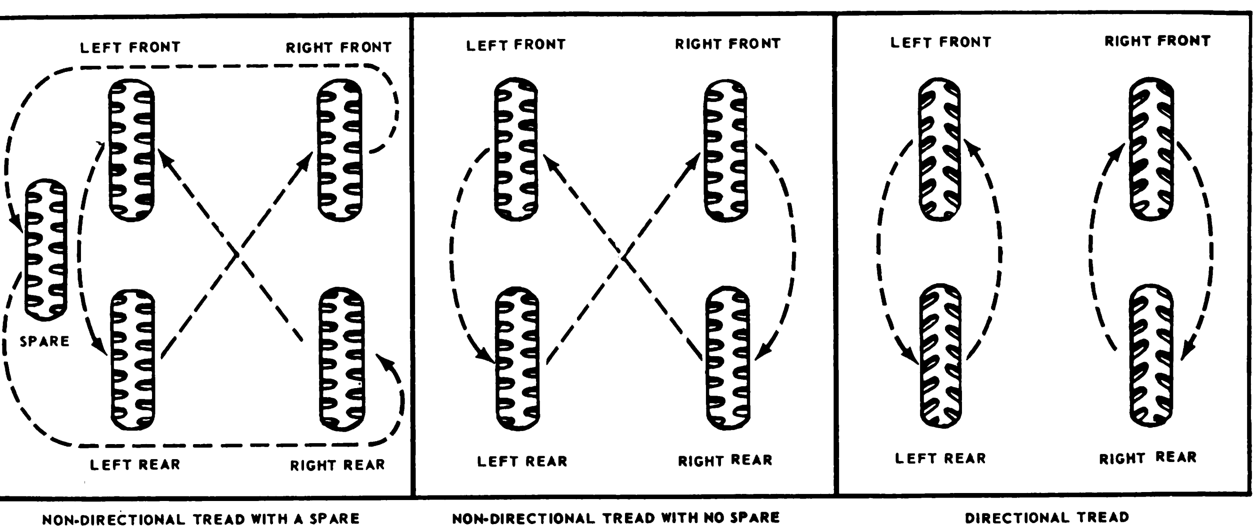


Figure 11-12.—Recommended tire and wheel rotation.

under cover in a cool, dry place. It is necessary that they be protected from light (especially sunlight). If inside storage is impossible and they must be stored in improvised shelters, the sidewalls should be coated with tire paint to help prevent tire deterioration. They should also be protected from excessive heat, dirt, and dampness.

Tires should be stored vertically in racks, according to size. They must never be stacked horizontally in piles. The issue of tires from the storeroom should be on a "first in, first out" basis so that the older tires will be used first, preventing the deterioration of the older tires in stock.

Tubes should be retained in their original cartons and stored on shelves so that they can be identified and reached easily. Tubes that have been repaired should be inflated enough to give them shape and stored on tube racks.

CHAPTER 12
TUBING AND FLEXIBLE HOSE

The ASH is responsible for the maintenance and repair of the fluid lines used in the operation of, or in conjunction with, ground support equipment. Fluid lines include any pipe, tubing, or flexible hose used to convey liquids or gases. This usually includes any rigid conduit used to house electrical wires or cables. Although pipe is used in some applications, tubing and flexible hose are the most common types of fluid lines used in ground support equipment.

Fluid lines pertaining to support equipment may be classified into two groups. One group consists of the lines which convey the liquids or gases necessary for the operation of the equipment. These include fuel, oil, coolant, and brake lines of powered servicing equipment such as tow tractors, and the hydraulic and pneumatic lines necessary for the operation of jacks, forklifts, workstands, etc. The other group consists of the lines used in conjunction with aircraft. These include hydraulic, compressed air, nitrogen, oxygen, and air-conditioning lines used in the servicing and testing of aircraft systems and components.

Keeping in mind the similarities and differences of these two groups, this chapter covers the identification, fabrication, and installation of tubing and flexible hose. Also included are some of the types of fittings and connectors used with the fluid lines in ground support equipment.

FLUID LINE IDENTIFICATION

Normally, no means of identification is required for the fluid lines used in the operation of support equipment. However, those lines used in the service and test of aircraft systems and components are usually identified by bands of paint, strips of tape, or metal tags around the line near each fitting. Various other information is also applied to the lines. This identification system is the same as that used in the identification of aircraft fluid lines.

Identification tapes are used on lines less than 4 inches in diameter except cold lines, hot lines, lines in oily environment, and lines used near aircraft engines where there is a possibility of the tape being drawn into the intakes. In these cases, and in all others where tapes should not be used, either painted identification is applied to the lines or metal tags are secured to the lines.

Identification tape codes indicate the function, contents, hazards, direction of flow, and pressure in the fluid line. These tapes are applied in accordance with MIL-STD-1247B. This Military Standard was issued in order to standardize fluid line identification throughout the Department of Defense. Figure 12-1 illustrates the method of applying these tapes as specified by this standard.

The function of a line is identified by use of a tape, approximately 1 inch wide, upon which word(s), color(s), and geometric symbols are printed. Functional identification markings, as provided in MIL-STD-1247B, are the subject of international standardization agreement. Three-fourths of the total width on the left side of the tape has a code color or colors which indicate one function only per color or colors. The function of the line is printed in English across the colored portion of the tape; therefore, even a non-English-speaking person can troubleshoot or maintain the equipment if he knows the code but cannot read English. The right-hand one-fourth of the functional identification tape contains a geometric symbol which is different for every function. This is to insure that all technicians, whether English speaking or not, who may be colorblind may still be able to positively identify the line function by means of the geometric design rather than by the color(s) or word(s). Figure 12-2 is a listing, in tabular form, of functions and their associated identification media used on the tape.

The identification-of-hazards tape shows the hazard associated with the contents of the line. Tape used to show hazards is approximately one-half inch wide, with the abbreviation of the hazard contained in the line printed across the tape. There are four general classes of hazards found in connection with fluid lines. These hazards are outlined in the following paragraphs.

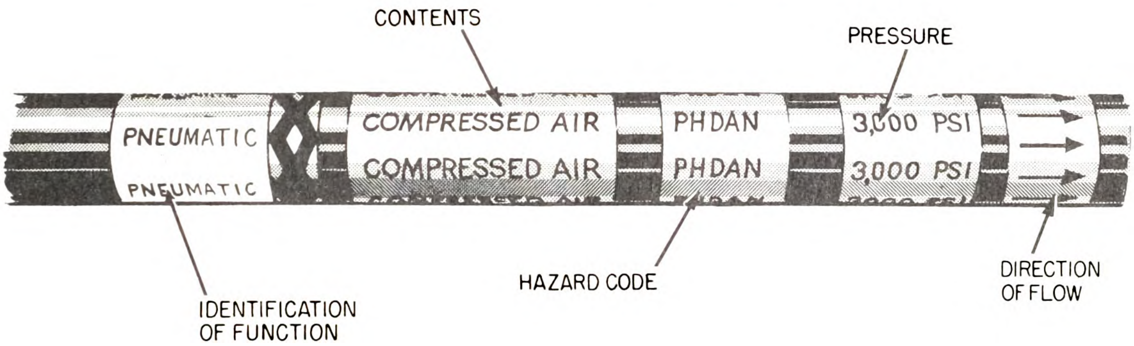


Figure 12-1.—Fluid line identification application.

Flammable material (FLAM). The hazard marking "FLAM" is used to identify all materials known ordinarily as flammable or combustible.

Toxic and poisonous materials (TOXIC). A line identified by the word "TOXIC" contains materials which are extremely hazardous to life or health.

Anesthetics and harmful materials (AAHM). All materials productive of anesthetic vapors and all liquid chemicals and compounds hazardous to life and property, but not normally productive of dangerous quantities of fumes, or vapors, are in this category.

Physically dangerous materials (PHDAN). A line which carries material which is not dangerous within itself, but which is asphyxiating in confined areas or which is generally handled in a dangerous physical state of pressure or temperature is identified by the marking "PHDAN."

Table 12-1 lists some of the fluids with which the ASH may be required to work and the hazards associated with each.

RIGID TUBING

Rigid tubing assemblies of ground support equipment are made up of aluminum alloy, stainless steel tubing, and copper. Copper tubing is used in some fuel systems, in certain parts of some oxygen systems, and in refrigeration units.

Two aluminum alloys are in common use—alloy 5052 may be used for lines carrying pressures up to 1,500 psi, and alloy 6061 for pressures up to 3,000 psi.

As a general rule, exposed lines and lines subject to abrasion, intense heat, or extensively high pressures are made of stainless steel.

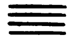
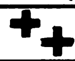
Flexible hose is generally used in connection with moving parts or where a line is subject to considerable vibration.

TUBING SIZES

The tubing used in the manufacture of rigid tubing assemblies is sized by outside diameter (OD) and wall thickness. Outside diameter sizes are in sixteenth-inch increments, and the number of the tube indicates its size in sixteenths of an inch. Thus, No. 6 tubing is 6/16 or 3/8; No. 8 tubing is 8/16 or 1/2; etc. Wall thickness is specified in thousandths of an inch.

TUBE FITTINGS

Fittings for tubing connections are made of aluminum alloy, steel, corrosion resistant steel (CRES), brass, and bronze. They are made in many shapes and forms, each designed to fulfill certain requirements. These include unions, tees, crosses, 45- and 90-degree elbows, bulkhead fittings, etc. Fittings are usually identified as to type with each type indicating the method used to form the fluid seal between the fitting and tubing. Three types—flared-tube, flareless-tube, and soldered fittings—are illustrated in figure 12-3. The flared-tube and the flareless-tube fittings are most commonly used and are described in the following paragraphs.

FUNCTION	COLOR	SYMBOL
Fuel	Red	
Rocket Oxidizer	Green, Gray	
Rocket Fuel	Red, Gray	
Water Injection	Red, Gray, Red	
Lubrication	Yellow	
Hydraulic	Blue, Yellow	
Solvent	Blue, Brown	
Pneumatic	Orange, Blue	
Instrument Air	Orange, Gray	
Coolant	Blue	
Breathing Oxygen	Green	
Air Conditioning	Brown, Gray	
Monopropellant	Yellow, Orange	
Fire Protection	Brown	
De-Icing	Gray	
Rocket Catalyst	Yellow, Green	
Compressed Gas	Orange	
Electrical Conduit	Brown, Orange	
Inerting	Orange, Green	

AM.67

Figure 12-2.—Functional identification tape data.

NOTE: Flared-tube fittings are identified by AN (Air Force-Navy) numbers and flareless-tube fittings are identified by MS (Military Standard) numbers.

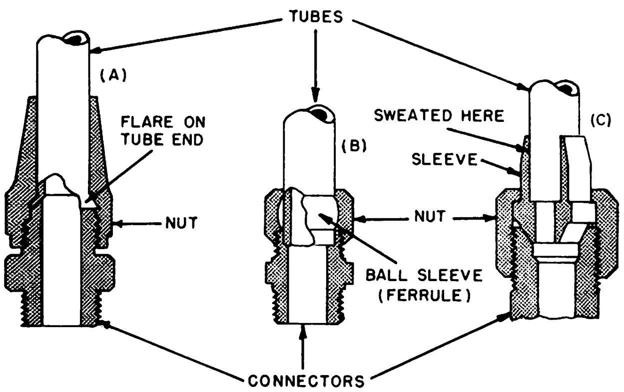
Flared-Tube (AN) Fittings

Flared-tube fittings have been widely used for many years and are still the most common type used in support equipment. Flared-tube fittings have either two or three parts. The fitting illustrated in figure 12-3(A) is made up of two parts—the body (connector) and the nut. The inside of the nut is cone-shaped. As the nut is tightened, the cone presses against the flared tubing and seals it against the connector.

The most common flared-tube fitting is the three-part fitting illustrated in figure 12-4. It

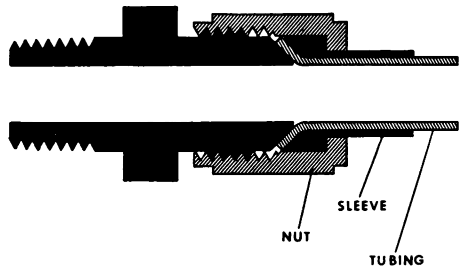
Table 12-1.—Hazards associated with various fluids.

Contents	Hazard
Air (under pressure)	PHDAN
Alcohol	FLAM
Carbon dioxide	PHDAN
Freon	PHDAN
Gaseous oxygen	PHDAN
Liquid nitrogen	PHDAN
Liquid oxygen	PHDAN
LPG (liquid petroleum gas)	FLAM
Nitrogen gas	PHDAN
Oils and greases	FLAM
JP-5	FLAM
Trichlorethylene	AAHM



AS.701
Figure 12-3.—Types of tube fittings.

is similar in design to the two-part fitting, with the addition of a sleeve. The sleeve fits directly over the tube, and one end is countersunk at the same angle as the tubing flare. The nut fits over the sleeve, and when tightened, draws the sleeve and tubing flare tightly against the male fitting (connector) to form the seal. The male fitting has a cone-shaped surface with the same angle as the inside of the flare. The sleeve supports the tube so that vibration does not concentrate at the edge of the flare, and distributes

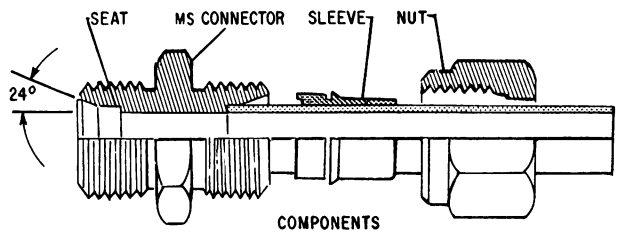


AM.68
Figure 12-4.—Flared-tube fitting.

the shearing action over a wider area for added strength.

Flareless-Tube (MS) Fittings

Flareless-tube fittings are sometimes referred to as bite-type or compression-type. However, the all-inclusive term, flareless type, is usually used in the field of aviation. Using this type fitting eliminates all tube flaring, yet provides a safe, strong, and dependable tube connection. The fitting shown in figure 12-5 consists of three units—a connector, a sleeve, and a nut. There are also special parts for close couplings and reducer couplings. NOTE: Flareless-tube fittings are not normally used in oxygen systems.



AM.69
Figure 12-5.—Flareless-tube fitting.

The connector accepts the straight tube end, plus the sleeve. This affects a seal at two points—one on the tube and one inside the fitting. At the time of manufacture, the connector port is counterbored large enough to accept the unflared tube end and a 24-degree countersink is then run almost to the bottom of the bore.

'his provides a tapered mouth large enough to ccept one end of the sleeve. When installed, he nut forces the sleeve deeper into the funnel-haped mouth of the connector and, as the sleeve nd is made to constrict, a cutting lip is em-edded in the tube, providing a seal at this oint. Further tightening causes the sleeve to ow slightly until a second seal is formed be-ween the sleeve and the bellmouth of the con-ector. After tightening, the bowed sleeve acts s a spring lock for the nut, which will retain t against the loosening effect of vibration. 'here is little chance that a flareless connec-ion will ever leak if it is assembled and in-talled correctly.

REMOVAL AND REPLACEMENT OF DAMAGED TUBING

All tubing is pressure tested prior to instal-ation and is designed to withstand several times he operating pressure to which it will be sub-ected. If a tube bursts or cracks, it is gener-lly the result of excessive vibration, improper nstallation, or from damage caused by colli-ion with an object. All tubing failures should e carefully studied and the cause of the failure etermined if possible. Replacements should e of the same size and material as the original r an acceptable substitute.

AYOUT OF LINES

A damaged line should be carefully removed o that it may be used as a template or pattern or the replacement item. If the old piece of ubing cannot be used as a pattern, an acceptable ne can be made by placing one end of a piece f soft iron wire into one of the fittings where he tube is to be connected. Form the neces-ary bends in order to place the opposite end f the wire into the other connection. When the emplate satisfactorily spans the area between he fittings, it can be used as a pattern to bend he new tube.

Select a path with the least total degrees of end, as this reduces flow loss and simplifies ending. Use a path with all bends in the same lane, if possible.

Never select a path that requires no bends. tube cannot be cut or flared accurately enough o that it can be installed satisfactorily without ends. Bends are also necessary to permit the ubing to expand or contract under temperature hanges and to absorb vibration. If the tube is small (under 1/4 inch) and can be hand formed, casual bends may be made to allow for this. If the tube must be machine formed, definite bends must be made to avoid a straight assembly.

Care must be taken to start all bends a reasonable distance from the end fittings, as the sleeves and nuts must be slipped back along the tube during the fabrication of flares and during inspections. In all cases, the new tube assembly should be so formed prior to installing that it is not necessary to PULL or DEFLECT the assembly into alignment by means of the coupling nuts.

TUBE CUTTING

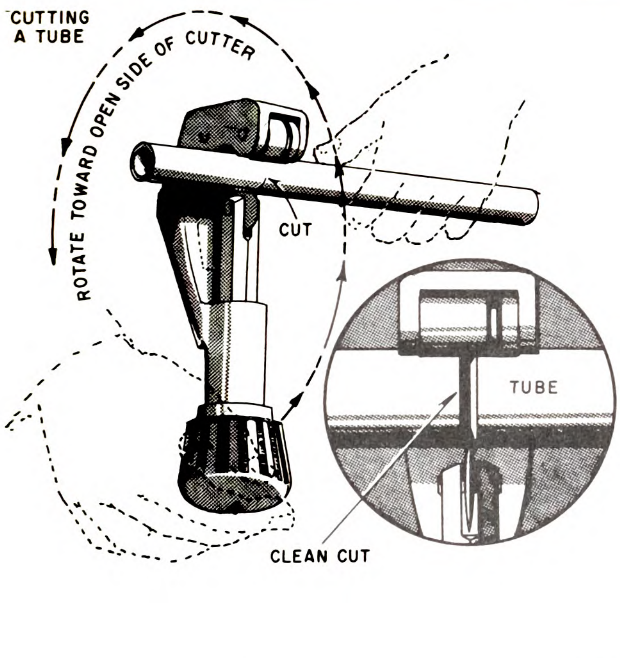
The ideal objective, when cutting tubing, is to produce a square end, free from burrs. Tubing may be cut with a tube cutter or a fine-tooth hacksaw.

Correct use of the tube cutter is shown in figure 12-6. The procedure is as follows: Place the tube in the cutter with the cutting wheel at the point where the cut is to be made. Tighten the adjusting knob so as to apply light cutter pressure on the tube, then rotate the cutter toward its open side, as shown in the illustration. As the cutter is rotated about the tube, continue to apply light pressure to the cutting wheel by intermittently tightening the knob. Too much pressure applied to the cutting wheel at one time may deform the tubing or cause excessive burrs. After the cut is completed, remove all burrs inside and outside, then clean the tube to make sure no foreign particles remain.

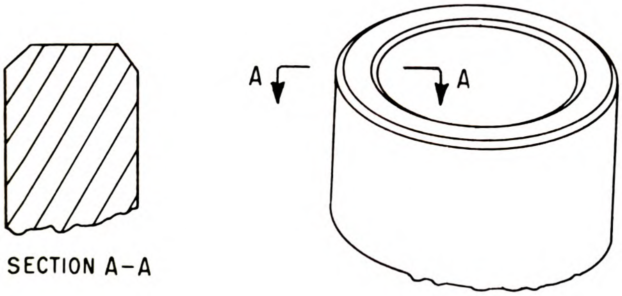
If a tube cutter is not available, a fine-tooth (32 teeth per inch) hacksaw may be used in cutting tubing. A convenient method of holding tubing when cutting it with a hacksaw is to place the tube in a flaring block and clamp the block in a vise. After cutting tubing with a hacksaw, all saw marks must be removed by filing. After filing, remove all burrs and sharp edges from the inside and outside of the tube as shown in figure 12-7. Clean out the tube and make sure no foreign particles remain.

TUBE BENDING

The objective in tube bending is to obtain a smooth bend without flattening the tube. Tube bending is usually accomplished with one of the tube benders discussed in this section; however, in case of an emergency, aluminum tubing under 1/4 inch in diameter may be bent by hand.



AM.70
Figure 12-6.—Tube cutting.



AM.71
Figure 12-7.—Properly burred tubing.

Hand Tube Bender

The hand tube bender shown in figure 12-8 consists of four parts—handle, radius block, clip, and slide bar. The radius block is marked in degrees of bend ranging from 0 to 180. The slide bar has a mark which is lined up with the zero mark on the radius block. The tube is inserted in the tool, and after lining up the marks, the slide bar is moved around until the mark on the slide bar reaches the desired degrees of bend on the radius block.

Mechanical Tube Bender

The tube bender shown in figure 12-9 is issued as a kit. The kit contains the equipment necessary for bending tubing from 1/4 inch to 3/4 inch in diameter.

This tube bender is designed for use with high-strength, stainless-steel tubing, as well as all other metal tubing. It is designed to be fastened to a bench or tripod, and the base is formed so as to provide a secure grip in a vise.

The simple hand bender shown in figure 12-8 uses two handles as levers to provide the mechanical advantage necessary to bend the tubing, while the mechanical type tube bender employs a handcrank and gears. The forming die is keyed to the drive gear and secured by a screw (fig. 12-9).

The forming die on the mechanical tube bender is calibrated in degrees similar to the radius block of the hand type bender. A length of replacement tubing may be bent to a specified number of degrees or it may be bent to duplicate the bend in the damaged tube or pattern. Duplicating the bend of a damaged tube or pattern is accomplished by laying the pattern on top of the tube being bent and slowly bending the new tube to the required bend. NOTE: Certain types of tubing are more elastic than others; therefore, it may be necessary to bend the tube past the required bend to allow for springback.

TUBE FLARING

A hand flaring tool similar to that shown in figure 12-10 is usually used for single flaring tubing. This tool consists of a flaring block or grip die, a yoke, and a plunger or flaring pin. The grip die consists of two steel blocks hinged at one end and held in alignment by a pilot pin. A number of countersunk holes, varying in size to conform with tube diameters and with countersinks matching standard flare angles and radii, are provided with half of the hole in each block.

The yoke fits over the two halves of the grip die and has a setscrew which is used to lock the yoke at the desired position. The yoke also serves as a centering guide for the plunger. The plunger is tapered to the same angle as the countersunk holes in the grip die.

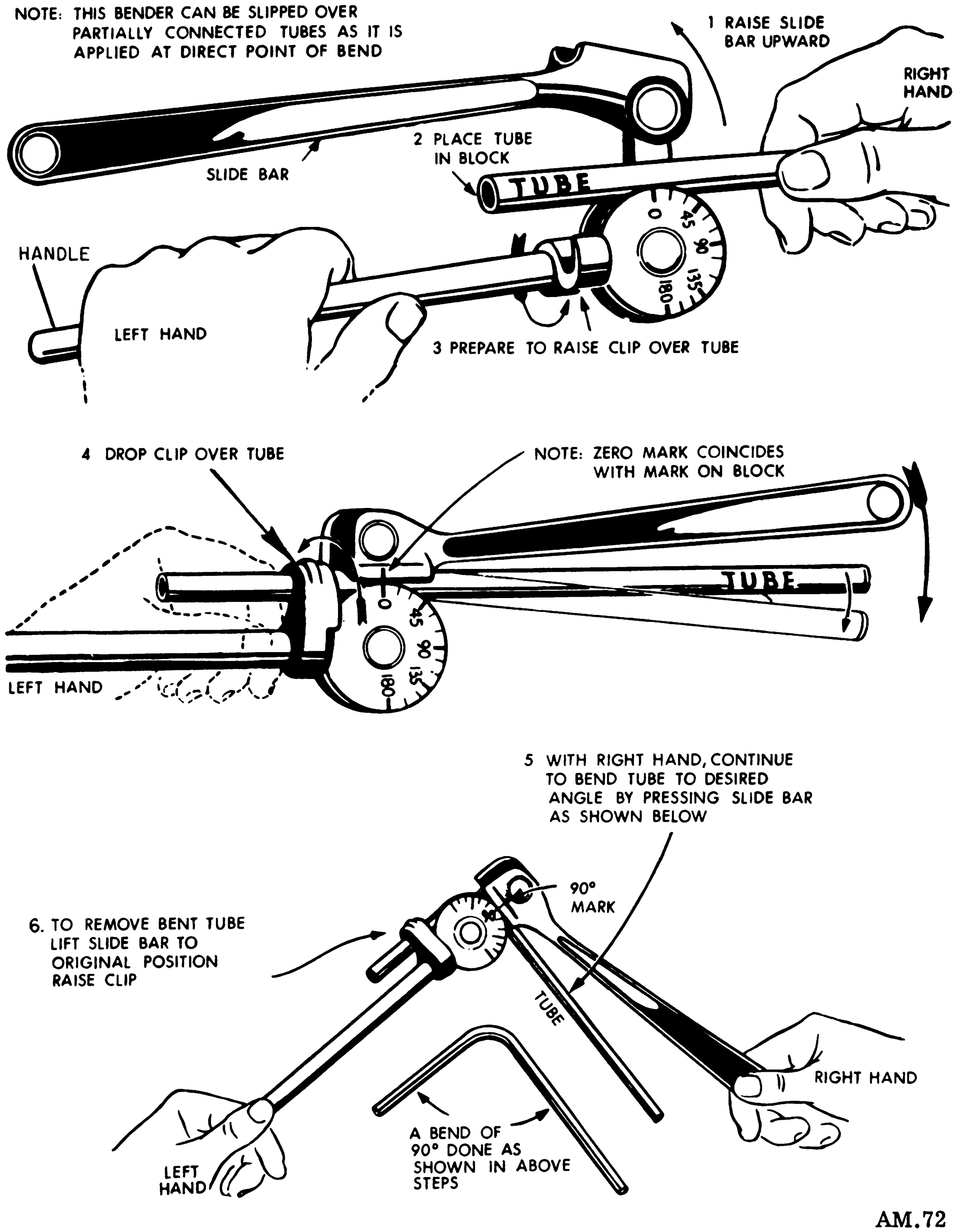
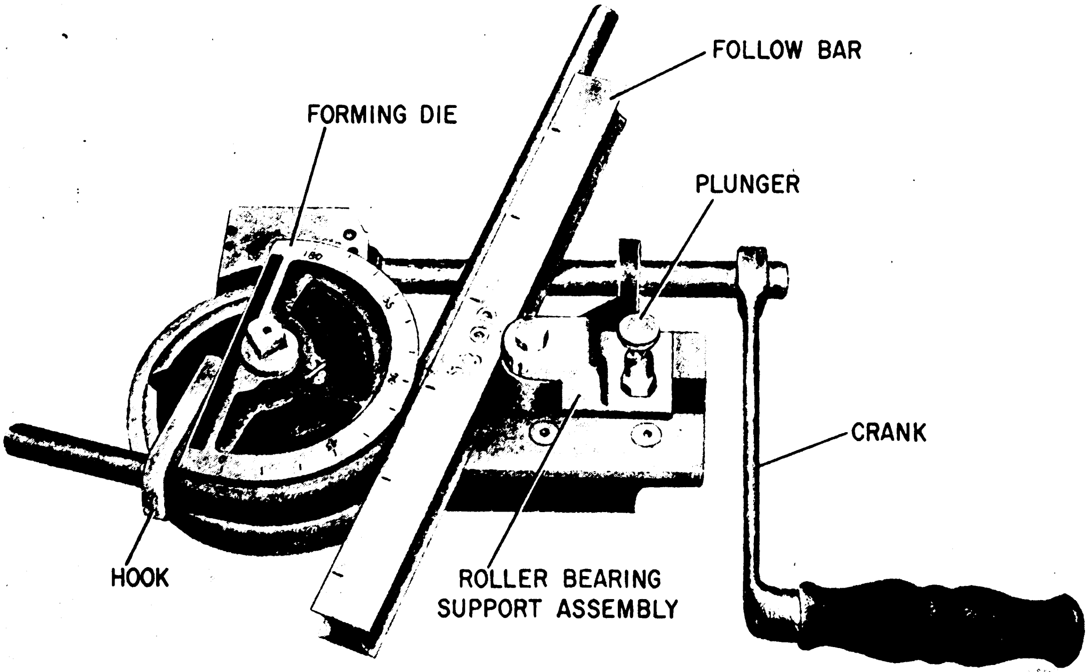


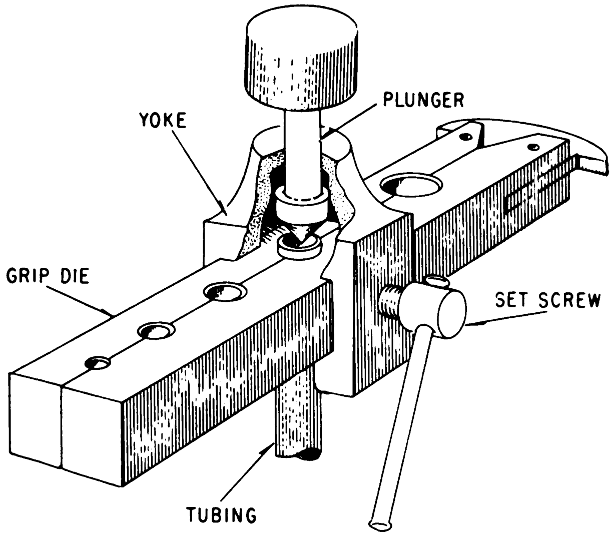
Figure 12-8.—Tube bending.

To flare the end of a tube with this tool, slip the fitting nut and sleeve onto the tube and place the tube in the proper size hole in the grip die. (The end of the tube should extend 1/64 inch above the surface of the grip die.) Center the plunger over the end of the tube and tighten the yoke setscrew to secure the tubing in the grip die and hold the yoke in place.



AM.73

Figure 12-9.—Mechanical tube bending tool.



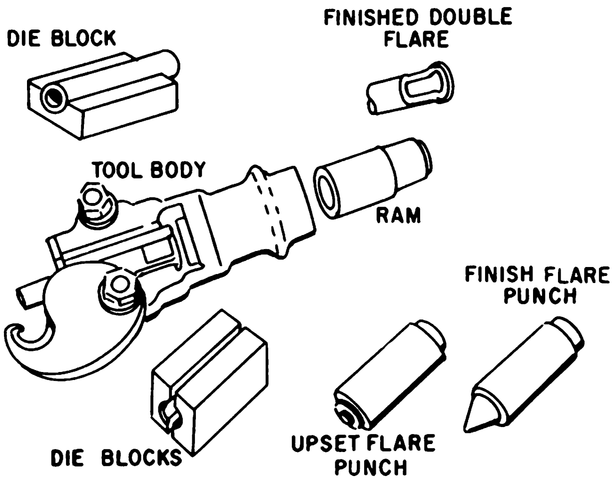
AM.74

Figure 12-10.—Tube flaring tool (single flare).

The flare is made by striking the plunger several light blows with a hammer or mallet. Turn the plunger a half turn after each blow and make sure it seats properly before removing the tube from the grip die. After completing the flare, inspect to insure that no cracks are evident. NOTE: The flared end of the tube should not be any larger than the largest diameter of the sleeve being used.

Double flares should be used on all 5052 aluminum alloy tubing up to 3/8-inch. Brake system tubing, which is usually steel, should be double flared. The double flare reduces cutting of the flare by overtightening and the consequent failure of the tubing assembly under operating pressure. Aluminum alloy and copper tubing used in low-pressure oxygen systems should always be double flared. Figure 12-11 shows one of the tools used in the manufacture of double flared tube assemblies.

This flaring tool is issued as a kit. The kit contains a tool body, a ram, and a finish flare punch. Also included are a set of die blocks



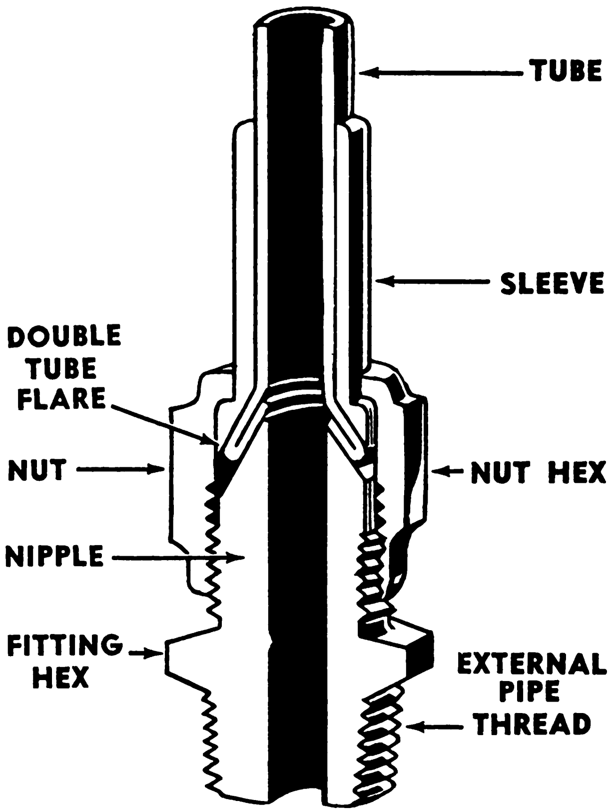
AM.75
Figure 12-11.—Tube flaring tool (double flare).

and an upset flare punch for each size of tubing which may be flared with this kit.

To double flare a tube assembly, prepare the end of the tube as shown in figure 12-7. Select the proper size die blocks and proceed as follows:

1. Place one-half of the die block in the flaring tool body with the countersunk end towards the ram guide.
2. Install the nut and sleeve and lay the tubing in the die block with approximately 1/2 inch protruding beyond the countersunk end.
3. Place the other half of the die block into the tool. Close the latch plate and tighten the clamp nuts finger tight.
4. Insert the upset flare punch in the tool body with the gage end toward the die blocks. NOTE: One end of the upset flare punch is counterbored or recessed to gage the amount of tubing needed to form a double lap flare. Insert the ram and tap lightly with a hammer or mallet until the upset flare punch meets the die blocks and the die blocks are firmly set against the stop plate on the bottom of the tool.
5. Tighten the latch plate nuts with a wrench. Tighten the nuts alternately, beginning with the closed side to prevent distortion of the tool.
6. Reverse the upset flare punch and insert it in the tool body. Insert the ram into the tool body and tap lightly with a hammer or mallet until the upset flare punch contacts the die blocks.
7. Remove the upset flare punch and ram. Insert the finishing flare punch and ram. Tap the ram lightly until a good seat is formed. Always check the seat at intervals during the finishing operation to avoid overseating.

A tube connection showing a finished double flare is illustrated in figure 12-12.



AS.702
Figure 12-12.—Double flared tube connection.

CAUTION: When fabricating oxygen lines, insure that all tools are kept free of oil and grease.

PRESETTING FLARELESS-TUBE FITTINGS

Although the use of flareless-tube fittings eliminates all tube flaring, another operation, referred to as PRESETTING, is necessary

prior to installation of a new flareless-tube assembly. Presetting is necessary to form the seal between the sleeve and the tube without damaging the connector.

Presetting should always be accomplished with a presetting tool such as the one shown in figure 12-13. These tools are machined from tool steel and hardened so that they may be used with a minimum of distortion and wear.

NOTE: A flareless-tube connector may be used as a presetting tool in case of an emergency. However, when connectors are used as presetting tools, aluminum connectors should be used only once and steel connectors should not be used more than five times.

Basically, presetting is accomplished by sliding the nut over the sleeve and turning it onto the threads of the presetting tool, as shown in figure 12-13. How tight the nut must be turned to set the sleeve will vary, depending upon the type and size of the fitting and also on whether or not a mandrel is used during the presetting operation. A mandrel consists of a short piece of solid bar of any hard material, such as steel, with an outside diameter from 0.002 to 0.005 inch less than the inside diameter of the tube. Its use is not mandatory in presetting sleeves but is recommended, since it supports the inside diameter of the tube and assists in attaining an improved sleeve cut during the presetting operation. For field use, a short piece of drill rod of the proper diameter may be used as a mandrel.

The length of the mandrel should be such that, when inserted in the tube, it provides support of the tube inside diameter at the sleeve cut and also at the point where the sleeve shoulder grips the tube.

The presetting operation is described in the following paragraphs.

NOTE: There are two types of flareless-tube fittings in current use. The older type consists of a short sleeve (MS21918) and a long nut (MS21917). The newer type consists of a long sleeve (MS21922) and a short nut (MS21921). The presetting operation for the two types differs to some extent. These differences are pointed out as applicable in the following discussion.

1. Cut the tubing to the correct length, with the ends perfectly square. Burr the inside and outside of the tube. Slip the nut and then the sleeve over the tube, making certain that the pilot and the cutting edge of the sleeve points toward the end of the tube. (See step 1 of fig. 12-13.) If a mandrel is used, it should be inserted in the tube at this time.

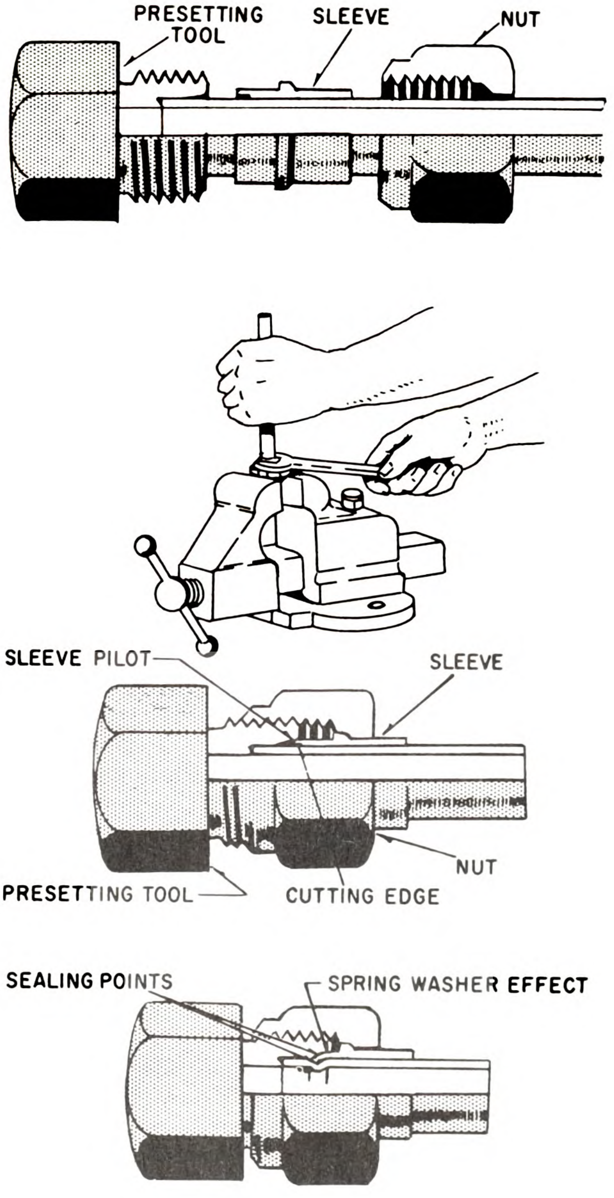


Figure 12-13.—Presetting flareless-tube assembly.

2. Lubricate the threads of the presetting tool and the nut with the approved lubricant. Hydraulic fluid, Specification MIL-H-5606 is the approved lubricant for hydraulic lines, and pneumatic grease, Specification MIL-G-4343,

is the approved lubricant for pneumatic lines. Refer to NA 01-1A-8, Structural Hardware, for the approved lubricants for other systems.

CAUTION: Hydraulic fluid or any other petroleum base lubricants must not be used as a thread lubricant for oxygen lines.

3. Place the tool in a vise and hold the tubing firm and square on the seat in the tool. (The end of the tube must bottom firmly in the tool.) The tube should be rotated slowly between the thumb and fingers while the nut is turned down until the sleeve seizes on the tube. When the tube no longer turns, the nut is ready for final tightening.

4. The final tightening force necessary to set the sleeve on the tube depends on the type of fitting. When presetting the older type fittings, tighten the nut (MS21917) 1 1/6 more turns for all sizes of tubing and all types of tubing material. This force sets the sleeve (MS21918) on the tube.

When presetting the newer type fitting—the long sleeve (MS21922) and the short nut (MS21921)—the required tightening force varies. If a mandrel is used, the final tightening force varies with the size of the tubing. If a mandrel is not used, the tightening force varies with the size, wall thickness, and material of the tubing. Tables of these tightening forces (turn values) are presented in NA 01-1A-8. These tables should be consulted when presetting this type fitting.

The final tightening force permanently assembles the sleeve to the tube. Sleeves should not be removed from the tube and reused under any conditions.

After presetting, the nut should be uncoupled from the presetting tool, and the sleeve and tube inspected for the following: (Refer to fig. 12-14.)

1. The sleeve cutting lip should be embedded into the tube outside diameter approximately 0.003 to 0.008 inch (distance (X) in figure 12-14), depending on the size and material of the tubing. As shown, a lip of material will be raised under the pilot. The pilot of the sleeve should contact or be quite close to the outside diameter of the tube. (See distance (y).) The tube projection from the pilot of the sleeve to the end of the tube (distance (Z)) should be approximately as listed in table 12-2. These figures will vary with wall thickness for a given size.

2. A slight collapse of the inner diameter of the tube at the sleeve cut and at the shoulder is permissible.

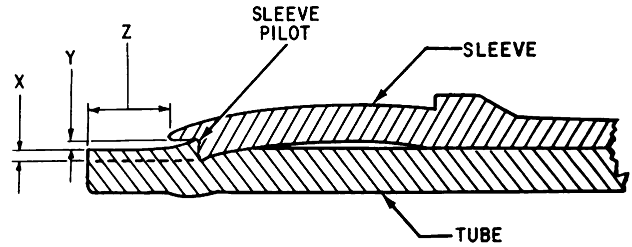


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Figure 12-14.—Preset sleeve—flareless-tube fitting.

Table 12-2.—Distance from sleeve to tube end.

Tube size	Approximate tube projection (inches)
3/16	7/64
1/4	7/64
5/16	5/32
3/8	11/64
1/2	3/16
5/8	13/64
3/4	7/32
1	15/64

3. The sealing surface of the sleeve must be smooth and free from nicks and scratches.

4. The sleeve should be slightly bowed and rotation of the sleeve is permitted. A 1/64-inch lengthwise movement of the sleeve is also permitted.

5. As a final check to determine that the fitting is properly preset, it should be proof tested at a pressure equal to twice the intended working pressure.

INSTALLATION OF TUBE ASSEMBLIES

Before a tubing assembly is installed, it should be carefully inspected. Dents and scratches should be removed (if possible without

weakening the tube) prior to installation. The proper nuts and sleeves should be installed and a proper fit obtained where the tubing is flared. Flareless assemblies should be checked for proper presetting. Each tube assembly should be proof pressure tested to twice its operating pressure prior to installation. The tubing assembly should be clean and free from all foreign matter.

The nuts should be hand screwed to the mating connector, then tightened with the proper wrench. The tubing assembly should not have to be pulled into place with the nut, but should be properly aligned prior to tightening.

Tubing which runs through cutouts should be installed with care so that it will not be scarred when worked through the hole. If the tubing assembly is long, the edges of any cutouts should be taped before the tubing is installed.

It is important to tighten tube fitting nuts properly. A fitting wrench or open end wrench should be used when tightening tube connections. NOTE: Pliers should never be used to tighten tube connections.

Flared-Tube Fittings

Correct and incorrect methods of installing flared-tube assemblies are illustrated in figure 12-15. The fitting should be tightened to the proper torque. The torque values vary depending on the size and material of the tubing and fittings and also on the type of system. As stated in chapter 5, never rely on memory for torque values. If the correct torque values are not listed in the applicable technical manual for the specific item of equipment, refer to the torque tables listed in NA 01-1A-8, Structural Hardware.

If an aluminum alloy tube assembly leaks after tightening to the required torque, it must not be tightened further. Overtightening may severely damage or completely cut off the tubing flare or may result in damage to the sleeve or nut. The leaking connection should be disassembled and the fault corrected. Common faults are as follows:

1. Flare distorted into the nut threads.
2. Sleeve cracked.
3. Flare out of round.
4. Flare cracked or split.
5. Inside of flare rough or scratched.
6. Connector mating surface rough or scratched.

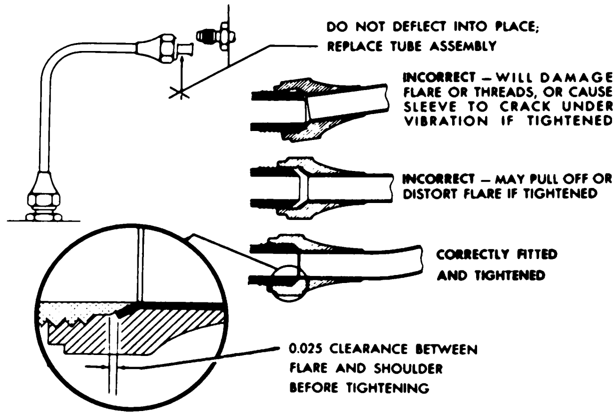

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Figure 12-15.—Correct and incorrect methods of installing flared fittings.

7. Threads of connector or nut dirty, damaged, or broken.

If a steel tube assembly leaks, it may be tightened 1/6 turn beyond the noted torque in an attempt to stop the leakage; then if unsuccessful, it must be disassembled and repaired.

Undertightening of connections may be serious, as this can allow the tubing to leak at the connector because of insufficient grip on the flare by the sleeve. The use of a torque wrench will prevent undertightening. CAUTION: A nut should never be tightened when there is pressure in the line, as this will tend to damage the connection without adding any appreciable torque to the connection.

Flareless-Tube Assemblies

When installing flareless-tube assemblies, inspect to insure that no scratches or nicks are evident and that the sleeve is properly preset.

Lubricate the threads of the nuts and connectors with hydraulic fluid. Place the assembly in the proper position and finger tighten clamps, brackets, supports, and nuts. NOTE: The tubing ends should fit snugly in the connectors and require little pressure to hold them in place.

CAUTION: Hydraulic fluid must not be used to lubricate fluid line connections in oxygen systems.

Like flared-tube assemblies, flareless-tube fittings should be tightened to the proper torque.

Torque values for flareless-tube fittings vary vith the size, wall thickness, and material of he tubing and fittings. Tables of these torque values are listed in NA 01-1A-8. It should be emphasized that the torque values differ for lare-tube and flareless-tube fittings. When checking torque values be sure that the torque able corresponds to the type of fitting.

If it is not possible to use a torque wrench, he following procedure should be used for ightening flareless-tube fittings.

Tighten the nut by hand until an increase in resistance to turning is encountered. Should it be impossible to run the nut down with the fingers, use a wrench, but be alert for the first signs of bottoming. It is important that he final tightening commence at the point vhere the nut just begins to bottom.

With a wrench, turn the nut 1/6 turn (one lat on a hex nut). Use a wrench on the connector to prevent it from turning while tightening the nut.

After the tube assembly is installed, the system should be pressure tested. Should a connection leak, it is permissible to tighten the nut an additional 1/6 turn (making a total of 1/3 turn). If, after tightening the nut a total of 1/3 turn, leakage still exists, the assembly should be removed and the components of the assembly should be inspected for scores, cracks, presence of foreign material, or damage from overtightening. NOTE: Overtightening a flareless-tube nut drives the cutting edge of he sleeve deeply into the tube, causing the tube o be weakened to the point where normal vibration could cause the tube to shear. After inspection (if no discrepancies are found), reassemble the connections and repeat the pressure test procedures.

CAUTION: Do not in any case tighten the nut beyond 1/3 turn (two flats on the hex nut); this is the maximum the fitting may be tightened without the possibility of permanently damaging the sleeve and tube.

FLEXIBLE HOSE

Flexible hose is used in connecting moving parts with stationary parts and in locations subject to severe vibration. It deteriorates rapidly; therefore, it is used only where absolutely necessary.

There are two general types of flexible hose—rubber and Teflon. These two types are described in the following paragraphs.

RUBBER

Flexible rubber hose consists of a seamless synthetic rubber inner tube covered with layers of cotton braid and wire braid, and an outer layer of rubber impregnated cotton braid. It is provided in low-pressure, medium-pressure and high-pressure types. Figure 12-16 illustrates the hose which is commonly used in medium-pressure applications. This hose is identified by the Military Specification number, the hose size, the quarter year and year of manufacture, and the hose manufacturer's symbol. This information is stenciled on the hose at intervals of not more than 9 inches and is connected by a series of dots or dashes. The stenciled information indicates the natural lay of the hose.

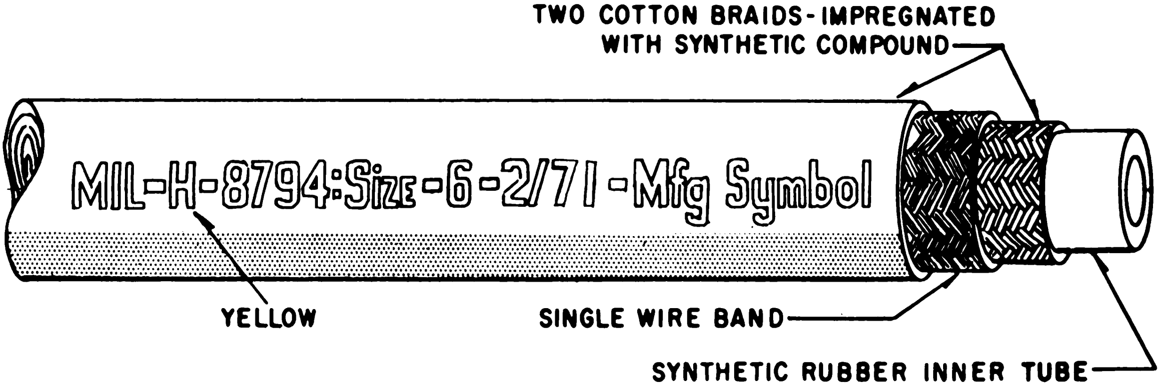

Figure 12-16.—Medium-pressure hose.

The size of flexible hose is determined by the inside diameter (ID) and indicated by a numbering system identical to that used with rigid tubing. Therefore, the fittings used on No. 6 hose will be the same size and have the same threads as those used on No. 6 (3/8 inch) tubing.

High-pressure hose is usually available in complete assemblies. These assemblies are equipped with swaged type fittings and are fabricated by commercial activities, Depot maintenance level activities, and those Intermediate maintenance level activities which have the required tools and equipment. Medium- and low-pressure hose assemblies are usually equipped with detachable type end fittings (described later) and may be fabricated at all maintenance levels.

Fabrication and Replacement

Flexible hose should be replaced if peeling, flaking of the hose cover, or exposure of the fabric reinforcement to the elements occurs.

When failure occurs in a flexible hose equipped with swaged end fittings, the unit is generally replaced without attempting a repair; that is, the correct length of hose, complete with factory-installed end fittings, is drawn from supply.

When failure occurs in low-pressure or medium-pressure hose equipped with detachable type end fittings, the replacement unit is usually fabricated in the shop. Undamaged end fittings on the old length of hose may be removed and reused; otherwise, new fittings must be drawn from supply along with a sufficient length of hose.

NOTE: Inspect bulk hose prior to use to insure that its shelf life has not expired. The shelf life of bulk rubber hose should not exceed 5 years (20 quarters) from the date of manufacture (cure date). The cure date is normally stenciled on the hose as shown in figure 12-16.

Figure 12-17 illustrates one type of detachable end fitting. This fitting is intended for use with medium-pressure hose which conforms to Specification MIL-H-8794. (Fittings for low-pressure hose are similar in design to this fitting.) This fitting is designed for use in flared-tube systems. Other hose fittings, which are designed to be used with flareless-tube fittings, are also available.

ASSEMBLY OF SLEEVE-TYPE FITTINGS.—Tool kits are available for assembling fittings to low- and medium-pressure hose. Figure 12-18 illustrates a hose assembly tool kit, which contains the assembly tools for use on the smaller sizes (3/16 through 3/4 inch) of hose.

Figure 12-19 illustrates the steps in assembling the MS24587 fitting, using the proper size assembly tool from the hose assembly toolkit.

NOTE: All the steps listed for the assembly of an MS24587 fitting to medium-pressure flexible hose (fig. 12-19) may be followed for the proper assembly of low-pressure hose.

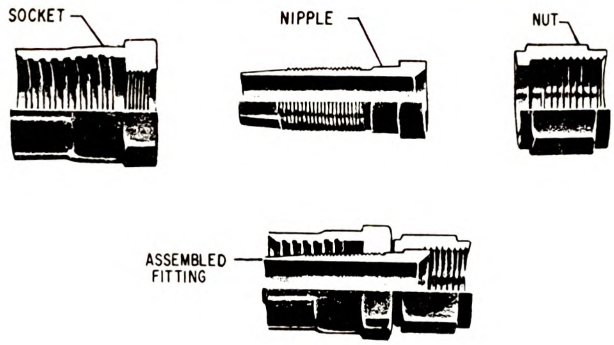

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Figure 12-17.—Sleeve-type flexible hose fitting (MS24587).

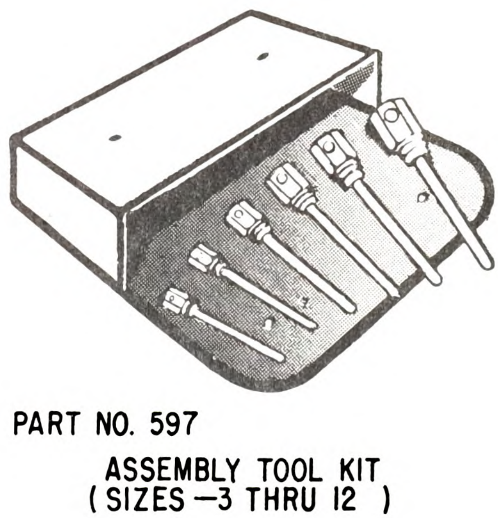

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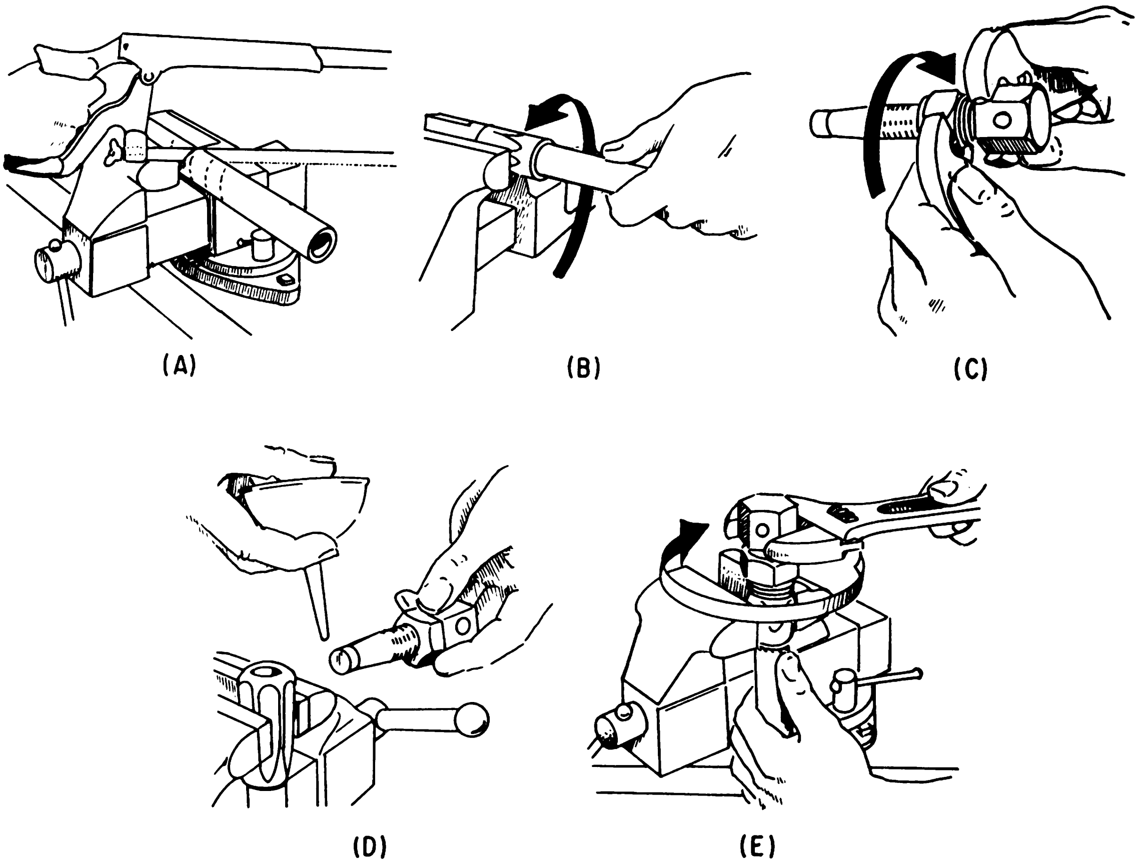
Figure 12-18.—Hose assembly tool kit.



A. Clamp the hose in the vise and cut the required length with a fine-tooth hacksaw.
B. Secure the socket in the vise. Turn the hose counterclockwise into the socket until it bottoms. Unscrew 1/4 turn.
C. Insert the nipple in the nut. Install the proper size assembly tool and tighten, using two wrenches.
D. Place the socket in the vise with the threaded end exposed. Lubricate the inside of the hose and the nipple threads with hydraulic fluid or light lubricating oil.
E. Using a wrench on the assembly tool, screw the nipple into the socket and hose. A clearance of 1/32 to 1/16 inch between the nut and socket is required so that the nut will swivel. Remove the assembly tool.

Figure 12-19.—Assembly of MS24587 fitting to medium-pressure flexible hose.

After assembly, always make sure all foreign matter is removed from the inside of the hose by blowing out with compressed air.

All shop-assembled flexible hose must be proof tested after assembly. Proof testing is accomplished by plugging or capping one end of the hose and applying pressure to the inside of the hose assembly. Proof testing equipment and procedures are described later in this chapter.

INSTALLATION OF FLEXIBLE HOSE ASSEMBLIES.—Flexible hose must not be twisted on installation, since this reduces the life of the hose considerably and may cause the fittings to loosen as well. Twisting of the hose can be determined from the identification stripe or printed information running along its length (shown in figure 12-16). This stripe or printed information should not tend to spiral around the hose.

The minimum bend radius for flexible hose varies according to size and construction of the hose and the pressure under which the hose will operate. Tables and graphs showing minimum bend radii for most types of installations are provided in Aircraft Structural Hardware, NA-01-1A-8. Bends which are too sharp will reduce the bursting pressure of flexible hose considerably below its rated value.

Flexible hose should be installed so that it will be subject to a minimum of flexing during operation. Hose should be supported at least every 24 inches. Closer supports are desired.

A flexible hose must never be stretched tight between two fittings. About 5 to 8 percent of its total length must be allowed as slack to provide freedom of movement under pressure. When under pressure, flexible hose contracts in length and expands in diameter.

TEFLON

Teflon hose is a flexible hose designed to meet the requirements of higher operating temperatures and pressures in present-day weapon systems. Teflon hose can generally be used in the same manner as rubber hose.

Teflon hose consists of a tetrafluorethylene resin which is processed and extruded into tube shape to a desired size. It is covered with stainless steel wire which is braided over the tube for strength and protection. The advantages of this hose are its operating temperature range (-67°F to 450°F), its chemical inertness to all fluids normally used in hydraulic and engine lubrication systems, and its long life. At this time, only medium-pressure and high-pressure types are available and are complete assemblies with factory-installed end fittings. These fittings may be either the detachable type or the swaged type. When failures occur, replacement must be made on a complete assembly basis.

The size of Teflon hose is determined in the same way the size of rubber hose is determined.

Teflon hose, like rubber hose, has definite limits and particular characteristics that demand understanding and attention in the general handling during installation and removal. To insure its satisfactory function and reduce the likelihood of failure, the following rules should be observed when working with Teflon hose:

1. Do not exceed recommended bend limits.
2. Do not exceed twisting limits.
3. Do not straighten a bent hose that has taken a permanent set.
4. Do not hang, lift, or support objects from Teflon hose.
5. Clamp the hose assemblies at least every 24 inches (more closely if possible) to lend support enough to prevent bending and kinking.
6. Do not permit flexible hose to impinge on, and thus possibly deflect, rigid supporting lines.
7. Allow a slight slack in the hose line to accommodate changes in length that will occur when pressure is applied.

Maintenance

Teflon hose, like all support equipment parts, has definite wearability limits. The chafing caused by hose rubbing against other surfaces, for instance, has undermined many parts and systems. Disaster consequent to such wear can be averted only through frequent inspection and maintenance by alert maintenance and quality assurance personnel.

INSPECTION.—Whereas all rubber hose must be inspected for aging and associated deterioration immediately prior to installation, Teflon hose, being comparatively inert, is exempt from shelf-life control. However, Teflon hose assemblies must be visually inspected for leakage, abrasion, and kinking. The presence and extent of the following possible defects must be determined.

Kinking.—Kinking is an imperfection induced in Teflon when it is bent at a closer angle (or shorter radius) than its characteristics allow. This is a common cause of failure, because Teflon hose tends to assume the shape of the position in which it is installed and becomes semipermanently set or "preformed" in these configurations. These so-called preformed hoses kink easily and their walls are severely weakened if they are excessively bent or twisted or if they are permitted to follow their natural tendencies to revert to their original shape. They must be handled very carefully while being

emoved and should be tied with wire that will old them in shape pending reinstallation.

Excessive Cold Flow.—Cold flow is the name iven the deep permanent impressions and racks in the hose cover caused by the pressure f the hose clamps. Replace hose when cold low becomes too deep.

Weather-Checking.—Weather-checking, the ccurrences of numerous fine cracks caused by xposure to various weather conditions over xtended periods, causes no serious damage so ong as it does not expose the fabric of the hose over. However, weather-checking deepened to he point of exposing this fabric can contribute o the weakening and eventual failure of the ose.

To examine the extent of weather-checking, latten the walls of the hose together, with force f necessary. If the cord fabric can be seen at ny point, replace the hose. The hose should lso be replaced if radial cracks at the end of he hose are deeper than one-eighth inch or are alfway from the ends of the hose to the clamps.

Internal Cracking.—Fuel hoses, both Teflon nd rubber, dry out and crack when they lose he plasticizer that keeps them pliable. Hoses emain pliable while in active use with fuel lowing through them but lose their plasticizers vhen the fuel is drawn off.

Therefore, fuel lines of previously used quipments that are to be returned to service fter extended storage must be inspected for nternal cracking. Those showing internal racks, which are revealed by pressing the ose with the fingers to widen imperfections, hould be replaced, while those showing no visble cracks at either end are considered satisactory throughout.

Separation of Outer Cover.—When the cotton raid or rubber coverings of metal-reinforced ose become loose, frayed, or chafed to the oint that the metal reinforcement is exposed r damaged, the hose should be replaced. If a ose shows some wear but the metal is not exposed or damaged, the frayed or chafed areas nay be wrapped in flexible, electrical-insulation leeving and secured over the hose with support lamps.

Wire-Braid Damage.—Wire-braid damage is onsidered excessive when two or more wires n a single plait or six or more in an assembly or lineal foot when assemblies are longer than 2 inches) are broken. Broken wires, where inking of the Teflon hose is suspected, are felt s sharp dents or twists in the braid.

CAUTION: When performing wire-braid damage checks, the Teflon hose must always be handled with great care so that broken wires do not injure the hands.

HOSE CHECK STANDS

All flexible hose assemblies which are fabricated locally should be pressure tested prior to installation. Two types of hose burst test stands, typical of those used for this purpose, are described in the following paragraphs.

Greer Test Stand

The flexible hose test stand shown in figure 12-20 is manufactured by Greer Hydraulics, Incorporated. Although this check stand is designed for proof testing aircraft hose assemblies, it may be used for most hydraulic and pneumatic hose assemblies. It is capable of developing static pressure up to 30,000 psi. The unit is mounted on four legs provided with mounting holes for bolting to the deck. Figure 12-21 shows the instruments and controls, and table 12-3 lists the functions of each. All personnel should familiarize themselves with these instruments and controls prior to using the check stand.

OPERATING PROCEDURES.—Prior to operation of the check stand, the following checks and adjustment should be made:

1. Make sure that the reservoir is filled with test fluid (MIL-H-5606).
2. Connect shop air supply line to the stand and open the air shutoff valve.
3. Turn the pressure regulator to the low-pressure position.

There are no special starting instructions since the stand starts to operate as soon as air pressure is admitted into the circuit by opening the air shutoff valve. The stand may be warmed up by capping all pressure outlet ports, opening the fluid outlet valve, and allowing the pump to operate for one minute.

With the air pressure regulator set at zero, lift the cover to the open position. Select the proper size adapter (with O-ring) to fit the hose line to be tested, and install them in the pressure manifold outlet port. Connect one end of the test hose line to the manifold adapter. Plug the manifold ports not being used. Connect the bleed valve to the adapter. Connect a second

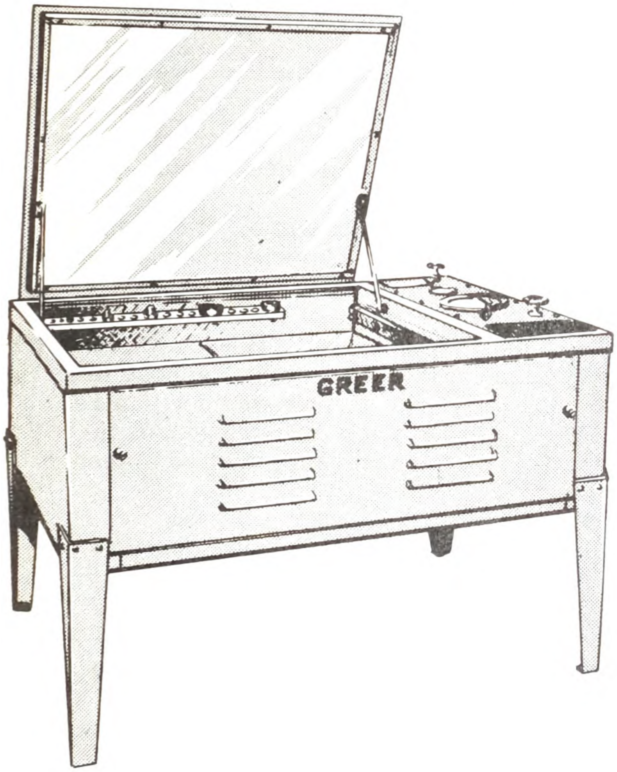


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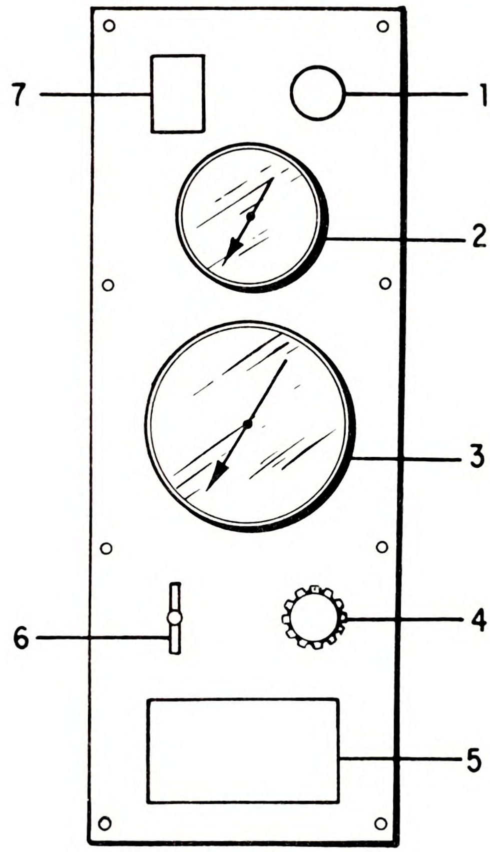
Figure 12-20.—Flexible hose check stand (Greer).



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1. Shop air shutoff valve.
2. Regulated air pressure gage.
3. Fluid pressure gage.
4. Air pressure regulator.
5. Schematic flow diagram.
6. Fluid outlet valve.
7. Nameplate.

Figure 12-21.—Instruments and controls of flexible hose check stand (Greer).

adapter on the other end of the test hose. Close the plexiglas cover before starting the test.

Hose lines should be tested in accordance with the applicable Military Specification, for example MIL-H-5593 or MIL-H-8794. Each hose specification gives proof-test pressures and other pertinent data for that particular type hose.

Static pressure is developed by closing the outlet valve and increasing pressure with the pressure regulator. The pressure in the test hose is indicated on the fluid pressure gage. The red following pointer will indicate the maximum pressure applied to the hose. This pressure may be increased or decreased by adjusting the pressure regulator.

After the test is complete, the stand is stopped by slowly opening the outlet valve and decreasing the pressure with the pressure regulator. When the fluid pressure gage reads zero, the plexiglas cover may be raised and the test hose disconnected and removed.

CGS Scientific Test Stand

The hose burst test stand shown in figure 12-22 is manufactured by CGS Scientific Corporation. This test stand provides a means for pressure testing flexible hose assemblies of various lengths and sizes. Hydraulic pressure up to 15,000 psi and pneumatic pressure up to

Table 12-3.—Function of controls and instruments (Greer test stand).

Index No.	Nomenclature	Function
1	Air inlet shutoff valve	Connects the shop air to the check stand.
2	Air pressure gage . . .	This is a 0-160 psi pressure gage. It registers the regulated air pressure being supplied to the booster pump.
3	Fluid pressure gage . .	This is a 0-30,000 psi gage. It is used to indicate the fluid pressure under which the hose lines are tested. This gage is provided with a red following pointer and manual reset (for indicating maximum pressure applied to test hose).
4	Pressure regulator . .	This is a relieving type air pressure regulator. It is used to set the air pressure to the booster pump to give the desired fluid pressure in the pressure manifold. Fluid pressure may be regulated by varying the adjustment on this regulator.
5	Schematic diagram . .	Mounted on instrument panel.
6	Outlet valve	This is a manual shutoff valve which is used to bleed air from manifold and to relieve fluid pressure upon completion of test.
	Bleed valve (located inside of test chamber).	There are six of these valves. They are used for bleeding air from hoses under test.
	Pressure relief valve (located under panel).	This is a diaphragm type air pressure relief valve. It is adjustable by means of an adjusting screw. This valve limits the air pressure to the desired maximum for safe operating condition. An audible whistling noise is indicated as a warning signal, preventing overpressure and possible damage to the stand components.

1,500 psi are available for the testing of hose assemblies. The test stand is a completely self-contained unit mounted on legs which permits bolting to the deck. Access doors and removable panels provide easy access to all components for maintenance. Figure 12-23 shows the controls and instruments, and table 12-4 lists the functions of each. All personnel should familiarize themselves with these controls and instruments prior to using the test stand.

OPERATING PROCEDURES.—Prior to performing the following preliminary adjustments, insure that the air and electrical systems are energized.

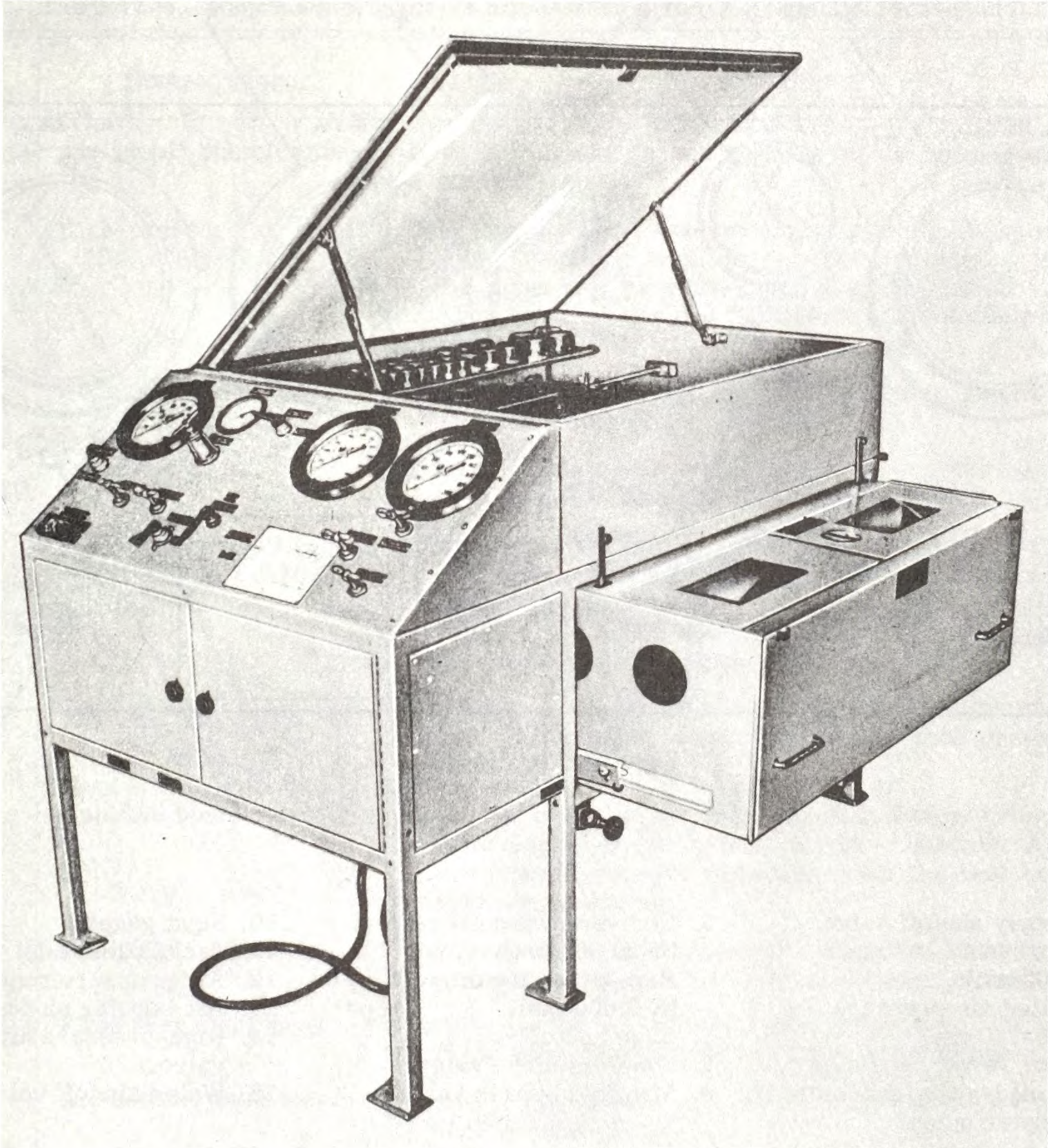

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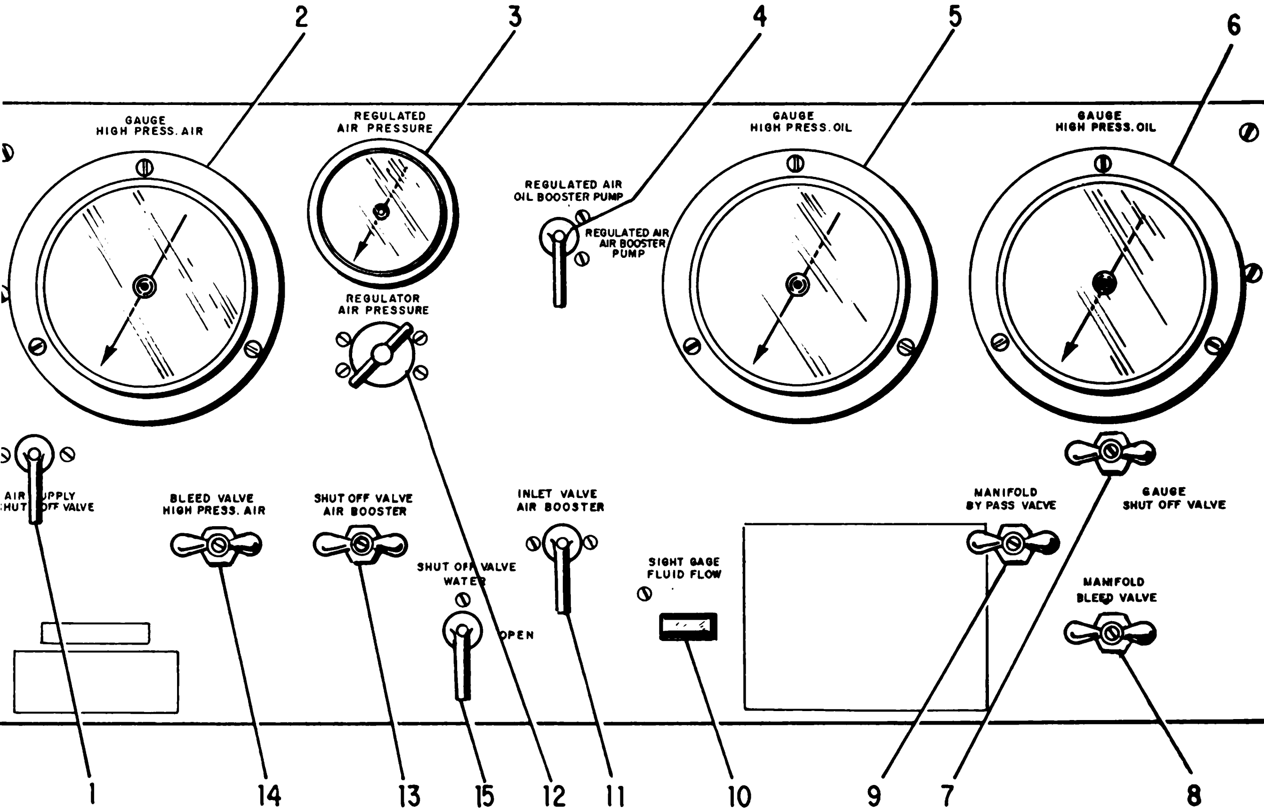
Figure 12-22.—Hose burst test stand (CGS Scientific).

1. Check the reservoir oil level. If the reservoir is not full, add hydraulic oil, Specification MIL-H-5606.
2. Make sure that the manifold bypass valve is closed.
3. Open the manifold bleed valve.
4. Make sure that the air booster inlet valve is closed.
5. Make sure that the high-pressure air bleed valve is closed.
6. Set the air pressure regulator for minimum pressure (fully counterclockwise).
7. Turn on the gage shutoff valve.
8. Set the red follower needles on the gages to zero.

Complete test procedures include the installation of the hoses, the pressure test, and the stopping operation. The test procedures for hydraulic hose are covered in the following



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. Air supply shutoff valve.
. High-pressure air gage (0-2,000 psi).
. Regulated air pressure gage (0-160 psi).
. Selector valve, regulated air to oil booster pump or air booster pump.
5. High-pressure oil gage (0-20,000 psi).
6. High-pressure oil gage (0-2,000 psi).
7. Gage shutoff valve.
8. Manifold bleed valve.
9. Manifold bypass valve.
10. Sight gage.
11. Air booster inlet valve.
12. Air pressure regulator.
13. Air booster shutoff valve.
14. High-pressure air bleed valve.
15. Water shutoff valve.

Figure 12-23.—Controls and instruments (CGS Scientific test stand).

aragraphs. These are followed with the comlete test procedures for pneumatic hose.

Installation of hose lines for the hydraulic est is accomplished as follows:

1. Open the Plexiglas door on the hydraulic est chamber.

2. Remove the plugs from the manifold orts.

3. Select the proper size adapters for the ose lines being tested and install them in the ıanifold ports.

4. Connect the hose lines to be tested between the two manifolds.

NOTE: The distance between the manifolds is adjustable for various hose lengths. Loosen the thumb screws which secure the rear manifold and slide it backward or forward on the tracks to obtain the desired distance.

5. Close the hinged door at the top of the test chamber.

As stated previously, flexible hose should be tested in accordance with the applicable Military

Table 12-4.—Functions of controls and instruments (CGS Scientific test stand).

Index number	Nomenclature	Function
1	Air supply shutoff valve.	Used for turning on and shutting off the shop air supply to the test stand.
2	High-pressure air gage (0-2,000 psi).	Indicates the air pressure being applied to the hose undergoing pneumatic test. A red follower pointer indicates the maximum pressure applied to the hose. A manual reset knob is provided for resetting the follower pointer to zero.
3	Regulated air pressure gage (0-160 psi).	Indicates the regulated air pressure being supplied to the oil boost pump or the air boost pump.
4	Selector valve.	Selects regulated air supply for the oil boost pump (hydraulic testing) or the air boost pump (pneumatic testing).
5, 6	High-pressure oil gages (0-2,000 and 0-20,000 psi).	Indicates the hydraulic pressure being applied to the hoses undergoing hydraulic test. A red follower pointer on each gage indicates the maximum pressure applied to the hoses. A manual reset knob is provided on each gage for resetting the follower pointer to zero.
7	Gage shutoff valve.	Provides a means for shutting off pressure to the 0-2,000 psi oil pressure gage when using test pressures in excess of 2,000 psi.
8	Manifold bleed valve.	Used for bleeding air from the test hoses and manifolds before applying full hydraulic test pressures. Also used to release hydraulic pressure from the test hoses and manifolds after test.
9	Manifold bypass valve.	Bypasses the manifolds when turned on. Used to relieve pressure on the manifolds at completion of test.
10	Fluid flow sight gage.	Provides a means for detecting air bubbles in the hydraulic oil passing from the bleed valve to the oil reservoir.
11	Air booster inlet valve.	Used to turn on and shut off the unregulated air supply to the air boost pump.
12	Air pressure regulator.	Used for setting the input air pressure to the oil boost pump during hydraulic testing to give the desired hydraulic test pressure. Also used for setting the input air pressure to the air boost pump during pneumatic testing to give the desired pneumatic test pressure.
13	Air booster shutoff valve.	May be turned off after pressure is built up in the test hose; it holds the test pressure and permits the air booster to be shut down.
14	High-pressure air bleed valve.	Provides a means for releasing the air pressure in the test hose after test.
15	Water shutoff valve.	Used for turning on the water to fill the pneumatic test chamber.

Specification. Each hose specification contains proof-testing pressures and other pertinent data for that particular type hose. The hydraulic test is performed as follows:

1. Make all the preliminary adjustments and install the test hoses as described previously.
2. Turn the selector valve to the oil boost pump position.
3. Turn on the air supply shutoff valve.
4. Slowly open the air pressure regulator until the air-free oil passes through the fluid flow sight gage, then close the manifold bleed valve.
5. Increase the pressure in the test hoses to the specified value by adjusting the air pressure regulator until the desired pressure is indicated on the high-pressure oil gages.

CAUTION: If pressure will exceed 2,000 psi, turn off the gage shutoff valve. This shuts off the pressure to the 0-2,000 psi high-pressure oil gage. Continue to read the 0-20,000 psi gage.

NOTE: While under test pressure, the test hoses may be observed through the Plexiglas window in the test chamber door.

NOTE: The pressure may be increased during the test by adjusting the air pressure regulator.

Upon completion of the hydraulic test, the operation of the test stand is stopped as follows:

1. Adjust the air pressure regulator for a zero reading on the regulated air pressure gage.
2. Close the air supply shutoff valve.
3. Open the manifold bypass valve.
4. When the high-pressure oil gage indicates a zero pressure, open the test chamber door and disconnect and remove the test hoses.

The test procedures for pneumatic hose are described in the following paragraphs. After performing all of the preliminary adjustments described previously, the installation of the hose line for the pneumatic test is accomplished as follows:

1. Unlock the two slide bolts which secure the pneumatic chamber in the retracted position. Pull out the chamber to the extended position and secure with the two slide bolts.
2. Unlatch and open the two doors at the top of the pneumatic chamber. Open the hinged screens inside the chamber.
3. Select a suitable adapter and connect the hose to be tested to the connection in the chamber. Using a suitable plug, seal the opposite end of the test hose.
4. Close the hinged screens. Close and lock the two doors at the top of the chamber.

Using the proof-test pressure listed in the applicable hose specification, the pneumatic test is performed as follows:

1. Make all preliminary adjustments and install the test hoses as described previously.
2. Turn on the air booster inlet valve.
3. Make sure that the air booster shutoff valve is turned on.
4. Turn the selector valve to the air boost pump position.
5. Turn on the air supply shutoff valve.
6. Increase the pressure in the test hose by adjusting the air pressure regulator until the desired pressure is indicated on the high-pressure air gage.

WARNING: Maintain the test hose at test pressure for 2 minutes before proceeding to step 7. A bursting test hose with water in the pneumatic chamber could cause injury to personnel.

7. Turn on the water shutoff valve and fill to the indicated level inside the test chamber.
8. Observe the test hose for air leaks through the shatterproof glass windows at the top of the test chamber. Air bubbles rising in the water indicate a leaking hose or fitting.

Upon completion of the pneumatic test, the operation of the test stand is stopped as follows:

1. Adjust the air pressure regulator for a zero reading on the regulated air pressure gage.
2. Shut off air supply shutoff valve.
3. Open the high-pressure air bleed valve.
4. When the high-pressure air gage indicates a zero reading, drain the water by means of the drain valve at the bottom of the chamber.
5. Open the test chamber doors and disconnect the test hose.

CHAPTER 13

FLUID POWER COMPONENTS

Fluid power is defined as power transmitted and controlled through the use of fluids, either liquids or gases, under pressure. This, of course, includes hydraulics and pneumatics.

Fluid power serves many functions in various items of ground support equipment. Hydraulic jacks and several models of workstands are operated principally with hydraulic power. The lifting and manipulating components of forklift trucks and weapons loaders are operated with hydraulics. The brakes of most self-propelled items of support equipment are operated with hydraulics, pneumatics, or a combination of the two. Hydraulics, of course, is the principal element in the operation of the test stands used to service and test aircraft hydraulic systems and in the operation of the test benches used for pressure and flow tests of hydraulic components. The major item of support equipment involving pneumatics is the air compressor system. The maintenance of these fluid power systems and components on all support equipment is one of the important responsibilities of the ASH.

This chapter and chapters 14 and 15 deal with hydraulics and pneumatics as applied to ground support equipment. Chapter 14 describes the operation and maintenance of typical hydraulic systems found in several different types of support equipment. Chapter 15, Brakes and Brake Systems, contains sections concerning hydraulic brake systems, pneumatic brake systems, and air-over-hydraulic brake systems.

This chapter contains a brief introduction concerning the fundamentals of fluid power, followed by sections which describe the operation and maintenance of hydraulic and pneumatic components found in ground support equipment.

NOTE: Obviously, it is impossible to adequately cover the broad field of fluid power in this training manual. The Rate Training Manual, Fluid Power, NavPers 16193-B, contains detailed discussions on the fundamentals of hydraulics and pneumatics and the operation of the various types of components found in fluid power systems. Fluid Power is one of the basic training manuals on the required reading list for personnel desiring to advance in the A rating. The entire manual is of interest to ASH; however, particular attention should paid to those chapters which pertain to the ar covered in the following discussion.

FUNDAMENTALS OF FLUID POWER

As previously mentioned, fluid power cludes power developed through the use of draulics and/or pneumatics. Hydraulics volves the use of liquids to produce power, pneumatics involves the use of gases to p duce power. Although liquids and gases are of the three different states of matter (so being the third), they have several similar ch acteristics. Because of these similar char teristics, both liquids and gases flow fr and for that reason are called fluids. The f damental characteristics of fluids are discus briefly in the following sections. Hydraulic discussed in the first section and is used a basis of comparison for pneumatics, whic covered in the second section.

HYDRAULICS

Hydraulics is the science pertaining to li pressure and flow. In its application to gro support equipment, hydraulics is the actio use of liquids, forced under pressure thro tubing and orifices, to operate various me anisms.

To understand hydraulics, the ASH must f be familiar with some of the characteristic liquids. First, a liquid has no definite sh but conforms to the shape of its container. T characteristic enables liquids to flow fre When sufficient liquid is forced into a syst the liquid fills all the lines and chambers c to it.

Another important characteristic is th liquid can be only slightly compressed. In s applications of hydraulics where extren close tolerances are required, the compr sibility of liquids must be considered in the sign of the system. However, in dealing with

hydraulic systems of ground support equipment, liquids are considered to be incompressible.

The third characteristic of liquid is its ability to transmit pressure. This is based on Pascal's law which states: Pressure applied to an enclosed or confined fluid is transferred equally in all directions without loss and acts with equal force on equal surfaces.

Figure 13-1 illustrates how these characteristics enable a liquid to transmit force. Notice that the liquid conforms to the shape of its container. In this case the container consists of the two cylinders and the line, including the bends, which connects the cylinders. Since liquid is practically incompressible, a downward movement of piston (1) displaces liquid from cylinder (1). The fluid flows through the line and into cylinder (2). To make room for this volume of liquid, piston (2) must move upward.

In order to understand how Pascal's law is applied to hydraulics, a distinction must be made between the terms FORCE and PRESSURE. Force may be defined as the push or pull exerted against the TOTAL AREA of a particular surface and is expressed in pounds. Pressure is the amount of push or pull on a UNIT AREA of the surface acted upon. In hydraulics, the unit area is the square inch; therefore, pressure is expressed in pounds per square inch, abbreviated psi. It is important to bear in mind that pressure is the amount of force acting upon 1 square inch of area.

Referring to figure 13-1, effort exerted on piston (1) and work accomplished by piston (2) are indicated in pounds and, thus, are both referred to as force. Since the confined liquid which transmits this force acts on all sides of the container, the result of these forces is indicated in psi (pressure).

Some means must be used to convert force to pressure and pressure to force. This is accomplished by using the formula F = PA, with F representing force (lb), P representing pressure (psi), and A representing area (sq in.). This form of the formula is used to find force when the pressure and area are given. To find pressure with force and area given, the formula is transposed to

$$P = \frac{F}{A};$$

and to find area with force and pressure given, the formula is transposed to

$$A = \frac{F}{P}.$$

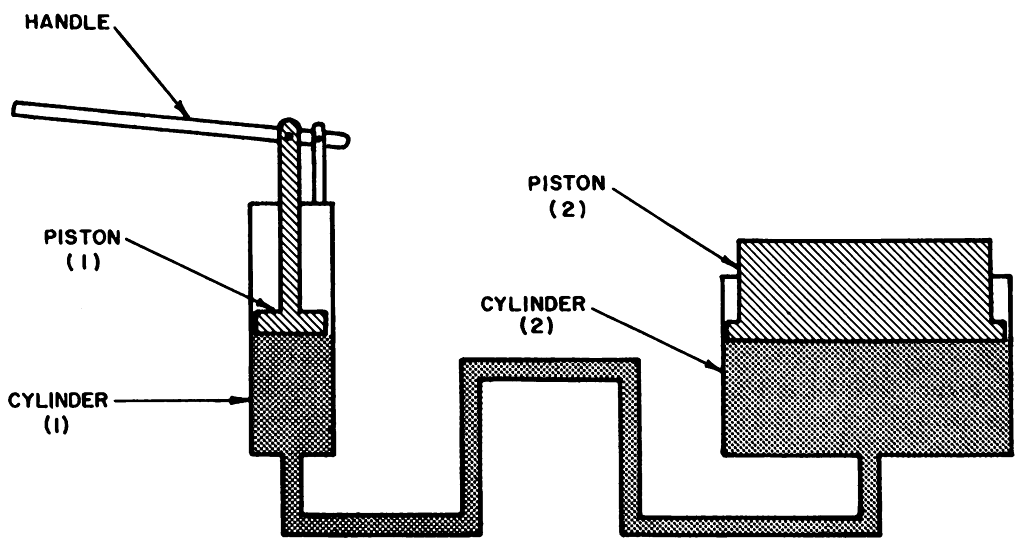

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Figure 13-1.—Transmission of force by liquids.

In applying this formula to the system illustrated in figure 13-1, assume that the area of piston (1) is 2 square inches and the area of piston (2) is 4 square inches. A 10-pound force applied to piston (1) will support a 20-pound resistant force acting against the top of piston (2). To prove this statement, first consider the pressure developed from the 10-pound force applied to piston (1). Substituting in the formula

$$P = \frac{F}{A},\ P = \frac{10}{2}$$

or 5 psi. This 5 psi is applied to the confined liquid and, in turn, to all sides of the container including the 4 square inch area of piston (2). Substituting in the formula F = PA, F = 5 x 4 or 20 pounds. Thus, the 10-pound force applied to piston (1) supports a force of 20 pounds acting against piston (2).

It must be remembered that the force exerted on piston (1), in this case 10 pounds, only creates a flow of liquid and that the resistance force, in this case 20 pounds, is required to create pressure. With no resistance against piston (2), any force exerted on piston (1) will develop only that pressure resulting from friction of liquid flow and the weight of piston (2).

For a more realistic application of this multiplication of forces, consider the system in figure 13-1 as that of a 10-ton hydraulic jack. (Complete jack hydraulic systems, which contain several additional components, are described in chapter 14.) Assume that piston (2) is the lifting piston and has an area of 10 square inches and that piston (1) is the pump and has an area of 1/4 square inch. These may not be the exact piston areas of any particular jack; however, they are realistic measurements. Next, assume that a 10-ton (20,000 pounds) load, the maximum capacity of the jack, is placed on piston (2). To support this force, a pressure of 2,000 psi must be exerted against the bottom of piston (2).

$$(P = \frac{F}{A},\ \text{or } P = \frac{20{,}000}{10} = 2{,}000 \text{ psi.})$$

To overcome this pressure of 2,000 psi and lift the 10-ton load, a force of slightly over 500 pounds must be applied to the top of piston (1). Substituting in the formula F = PA, F = 2,000 x 1/4 or 500 pounds. Thus, 500 pounds of force applied to piston (1) will equal the resistant pressure of 2,000 psi and support or balance the load. A very slight additional force will then force the liquid from cylinder (1) to cylinder (2) and raise the load.

Obviously, one man cannot apply 500 pounds of force to piston (1) without some assistance. In this case the assistance is the mechanical advantage of the lever. For example, assume that the handle in figure 13-1 is a 14-inch lever with an effort arm of 12 inches and a resistant arm of 2 inches. This gives a mechanical advantage of 6. Thus, it requires less than 85 pounds of force on the end of the handle to apply over 500 pounds of force to piston (1). (The Rate Training Manual, Basic Machines, NavPers 10624-A, should be consulted for complete and detailed descriptions of the classes of levers.)

Neglecting friction in any mechanical system, the total work input is always equal to the total work output. Since the output force is greater than the input force in the hydraulic system previously described, something is lost in this transmission of force. The loss is in the difference of piston travel. When piston (1) in figure 13-1 is forced downward, the volume of liquid displaced from cylinder (1) flows into cylinder (2). Since cylinder (2) is larger than cylinder (1), obviously, piston (2) will not move as far as piston (1). Thus, the input force, multiplied by the distance through which it travels, is always exactly equal to the output force multiplied by the distance through which it travels.

PNEUMATICS

Pneumatics is that branch of fluid power which pertains to gaseous pressure and flow. This differs from hydraulics in that gases, usually compressed air or nitrogen, rather than liquids are used to transmit forces.

The characteristics of a confined gas are very similar to those of a confined liquid. Like liquid, a gas has no definite shape but conforms to the shape of its container. In fact, a gas will always fill its container, while a liquid may not. Pascal's law applies to gases and, therefore, gases transmit forces the same as liquids.

Unlike liquids, gases are highly compressible. This characteristic is the major difference between liquids and gases. Because of this characteristic, gases provide a much less rigid force than do liquids. For example, compare the hydraulic system in figure 13-1 to an identical system filled with gas rather than liquid. It would require the same amount of force on

:on (1) of either system to overcome equal istant forces acting against piston (2) of ıer system. However, due to its compresility, a gas decreases in volume as it inases in pressure. Therefore, in the gaseous tem, a large portion of the travel of piston is utilized in the compression of the gas. · this reason, gases for pneumatic systems compressed in advance and stored in conıers. The gas is then released, in sufficient ıme and at the correct pressure, from the tainer into the pneumatic system to accomsh the required work.

COMPONENTS

Although the system illustrated in figure 13-1 ves to demonstrate the fundamental prinles of fluid power, several additional coments are required for a complete workable d power system. For example, the most ic hydraulic system requires a reservoir, a np, a control or selector valve, an actuator, tubing or flexible hose to connect these nponents. Most fluid power systems contain or more additional components. These inde such items as pressure relief (safety) ves, filters, accumulators, pressure gages, .

The maintenance of fluid power systems indes troubleshooting—locating and determin- the causes of malfunctions in fluid power tems. (Troubleshooting procedures are dissed in chapter 14.) In order to locate the ses of malfunctions, the ASH must underıd the operation of the system. To underıd system operation, the ASH must know the :tion, the operation, and the interrelation- of the components which make up the tem.

As previously mentioned, Fluid Power, Nav's 16193-B contains information concerning purpose and operation of fluid power compots in general. Since the material in the foling sections covers representative compots of the types used in the fluid power systems ground support equipment, this information ntended to supplement, rather than repeat, information given in Fluid Power. There-, the applicable chapters of Fluid Power uld be studied in conjunction with the follow- discussions.

After determining the cause of a system function, the ASH, in many cases, must re- the defective component. In some instances the component may be repaired without removing it from the system. However, in the majority of cases, the component must be removed for repair. Component maintenance also includes testing. Defective components must be tested on a test bench to determine the cause of malfunctions. The repair of a component is not considered completed until the component has been tested. Also, new components should be tested before they are installed in a system. (The use of the component test bench is covered in chapter 14.)

The extent of component repair depends upon the design and complexity of the component and the availability of replacement parts, tools, equipment, and qualified personnel. The most common cause of component malfunction in a hydraulic system is the result of dirt or other foreign particles in the system. This can usually be eliminated by flushing the system. (Flushing procedures are covered in chapter 14.) Sometimes foreign particles become lodged in a component. If this happens, the component must be removed, disassembled, and cleaned. During this procedure, the parts and seals must be inspected, since foreign particles tend to damage seals and scratch or score closely fitted machine parts. After all defective seals and parts have been replaced and the parts reassembled, the component must be tested before installation.

NOTE: The procedures for disassembly and reassembly differ from one component to another. For this reason, the applicable Repair Instructions Manual should be consulted for the proper procedures to be followed in each case. Accepted tolerances of component parts are also included in these manauls. The replacement of seals is covered in chapter 5.

RESERVOIRS

Each fluid power system requires a source of fluid supply. The component in a pneumatic system which provides this function is often referred to as a receiver. The receiver is usually considered part of the compressor system and, for this reason, is described later in this chapter under air compressors.

The reservoir, sometimes referred to as a tank, serves as a source of fluid supply in a hydraulic system. In addition, the reservoir also serves to dissipate heat, trap foreign particles, and separate air from the fluid. The size

and the design of a hydraulic reservoir depend upon the hydraulic system. For example, the reservoir for an automatic transmission also serves as a housing for the assembly. In most hydraulic brake systems, the reservoir and master cylinder, although two separate units, are physically contained in one housing, while in common hydraulic jacks and workstands, the reservoir serves as a housing for the pump and other components. However, in most hydraulic systems the reservoir is a separate component.

A typical hydraulic reservoir is illustrated in figure 13-2. The housing is constructed of heavy gage metal and is usually welded at the seams. The size of the reservoir must accommodate the hydraulic system; however, the shape may sometimes be designed to fit into some convenient location in the particular item of equipment. Inspection plates are generally installed on the top or sides of the reservoir to provide easy access for cleaning. A plug or valve is located at the lowest point in the bottom of the reservoir to provide a means for draining.

The hydraulic reservoir requires a means of equalizing the air pressure in the top of the reservoir with the surrounding atmospheric pressure. This is accomplished by the incorporation of an air breather in the top of the reservoir. The breather may be a separate unit or it may be incorporated into the filler cap as indicated in figure 13-2. An air filter is incorporated in the air breather. The filler neck usually contains a strainer.

A space is provided above the required fluid level in a reservoir to allow for thermal expansion of the fluid. This also allows space for the fluid to foam and air to purge from the fluid. Some method must be provided to check the fluid level in the reservoir. Some reservoirs are provided with a sight gage on the side of the reservoir. In others, the filler neck is recessed into the top of the reservoir. With the reservoir filled to the bottom of the filler neck, the required air space is provided.

There are two main ports in the reservoir. One serves as an outlet to supply fluid to the

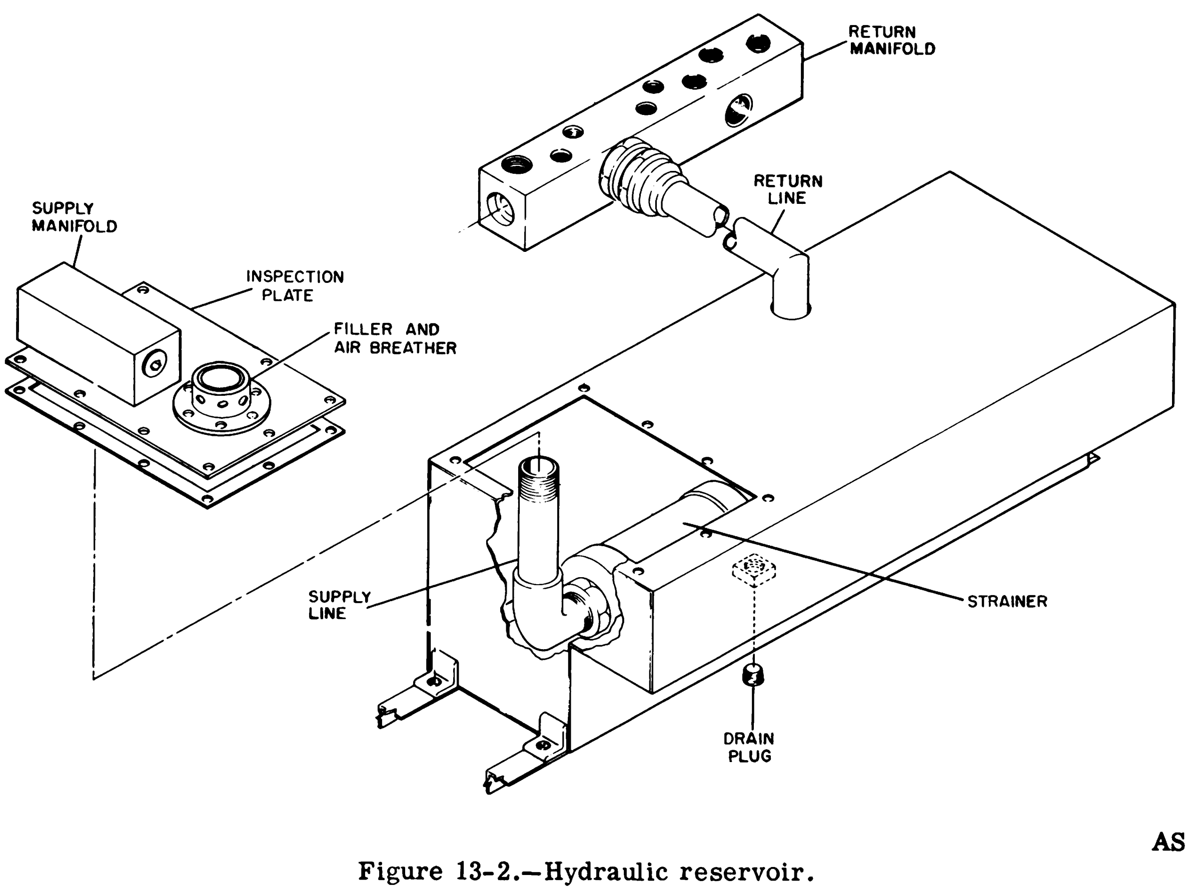

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Figure 13-2.—Hydraulic reservoir.

ump, and the other serves as an inlet for return luid from the system. A strainer is attached o the supply port on the inside of the reservoir. n some systems, the supply line is connected irectly to the pump and one line serves as a eturn line with subsystem return lines conected to it at appropriate places. Some sysems are provided with manifolds in the supply nd return lines. (See fig. 13-2.) A manifold s a fluid conductor which provides multiple conection ports. In this system the reservoir suplies fluid to three pumps through one manifold. One line supplies fluid to the manifold, and three ines supply the fluid from the manifold to the hree pumps. Similarly, each subsystem return ine is connected to the return manifold, and one ommon line returns the fluid from the manifold o the reservoir.

Cleanliness is the primary concern in servcing and maintaining hydraulic reservoirs. Although servicing a reservoir is a simple operation, certain procedures and precautions must be followed. Specific directions are conained in the applicable Service Instructions Manual. In addition, some reservoirs are provided with a placard or information plate which s located on or near the reservoir. This placard or information plate contains detailed information necessary for servicing the reservoir. This includes such information as reservoir capacity, fluid type, and caution notes. Precauions to be observed during the handling of hydraulic fluid are listed in chapter 14.

POWER SUPPLY

To accomplish work, fluid power systems require some means to provide a flow of fluid. Pumps are utilized to provide this requirement n hydraulic systems. Although the volume and pressure of the gas itself provides the flow in a pneumatic system, some means must be utiized to compress the gas. The air compressor s commonly used for this purpose and is, therefore, considered the source of power for pneumatic systems. However, the design and the operation of the air compressor differ to some extent from that of the hydraulic pump. In addition, the receiver, the valves, and other components required in the operation of the compressor are usually considered as a part of the compressor. Since many of these components are described in the succeeding sections of this chapter, the operation of a complete air compressor system is covered in the last section of this chapter. Hydraulic pumps, however, are discussed in the following paragraphs.

Hydraulic Pumps

The purpose of the pump in a hydraulic system is to supply a flow of fluid to the system. Referring to the discussion concerning the system illustrated in figure 13-1, a force exerted against the top of piston (1) provides a flow. No pressure is created until a resistant force is applied to piston (2).

There are several methods of classifying hydraulic pumps. One common method is by the source of power used to operate the pump. Pumps which are driven by electric motors, gasoline engines, or diesel engines are referred to as power pumps. Pumps which are manually operated are referred to as hand pumps.

Pumps may also be classified as to the type of design used to create the flow of fluid. Hydraulic pumps fall within three main types of design—centrifugal, rotary, and reciprocating. Of these, the rotary and reciprocating types are most commonly used in hydraulic systems of support equipment. The rotary pump is further classified as to the type of rotating element. Gears, lobes, and vanes are all used as rotating elements. Of these, the gear pump is most commonly used in the hydraulic systems of support equipment. The vane type pump is used in some systems.

Some form of the reciprocating pump is perhaps the most common type of hydraulic pump found in ground support equipment. This type pump depends upon the reciprocating (back-and-forth) motion of a piston inside a cylinder. The hand pump and the master brake cylinder are examples of reciprocating hydraulic pumps. There are also several types of power-driven reciprocating pumps.

HAND PUMPS.—There are two major types of hand pumps—the single-action and the double-action. In a single-action pump, the fluid is drawn into the cylinder on the first or suction stroke and is forced out of the cylinder on the return or discharge stroke. The double-action pump provides flow during each stroke of the piston. Both classes of hand pumps are utilized in the hydraulic systems of ground support equipment. For example, the double-action pump is used in weapons loaders as an emergency source of hydraulic power. This type pump is also used in hydraulic component test benches. The single-action pump is the common

source of power for hydraulic jacks and hydraulically operated workstands.

The operation of the double-action hand pump is described in detail in Fluid Power, NavPers 16193-B, and is therefore not covered in this training manual. The single-action hand pump is discussed in the following paragraphs.

The single-action hand pump operates similar to piston (1) in figure 13-1. However, some means must be provided to trap the fluid in the system and allow a new supply of fluid to enter the pump chamber during the return stroke. This is normally accomplished through the use of check valves.

A schematic of a typical single-action hand pump is illustrated in figure 13-3. Pumps of this type are used in hydraulic jacks and hydraulically operated workstands.

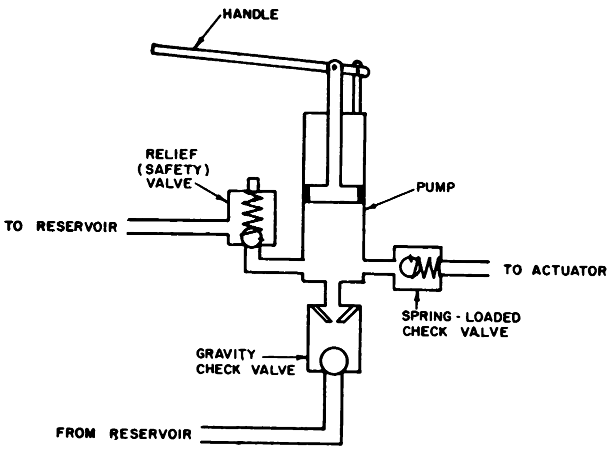

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Figure 13-3.—Single-action hydraulic hand pump—schematic.

During the UP or suction stroke of the pump, any pressure in the line to the actuator, plus spring tension, holds the ball of the spring-loaded check valve on its seat. This traps the fluid in the line to the actuator. The relief valve also remains closed at the time. As the piston moves upward, a low-pressure area (a pressure lower than the surrounding atmospheric pressure) is created in the lower chamber of the cylinder. Remember that atmospheric pressure is acting on the surface of the fluid in the reservoir. This fluid, under the force of atmospheric pressure, forces the ball of the gravity check valve off its seat. Fluid then flows from the reservoir into the low-pressure area of the pump cylinder.

During the DOWN or power stroke, the force exerted on the piston forces fluid against the gravity check valve and the spring-loaded check valve. This force immediately overcomes the force of atmospheric pressure and forces the ball of the gravity check valve into its seat. Fluid is then trapped in the lower portion of the pump cylinder, causing a resistant force against the bottom of the pump piston.

As the piston continues the DOWN stroke, the resistant force increases the pressure of the trapped fluid. The pressure increases until it overcomes the pressure of the fluid in the line to the actuator plus the tension of the spring in the spring-loaded check valve. This forces the ball of the spring-loaded check valve off its seat. The fluid then flows from the pump cylinder into the line to the actuator.

The spring tension of the relief (safety) valve (fig. 13-3) may be adjusted. It is adjusted to relieve at a pressure slightly above the pressure required to overcome the maximum force that may be exerted on the actuator. For example, assume that the actuator is the ram cylinder of a 10-ton hydraulic jack. The rated load of this jack is 20,000 pounds. The maximum allowable load is approximately 10 percent above the rated load or, in this case, 22,000 pounds. Therefore, the relief valve is set to relieve at that pressure required to lift a load in excess of 22,000 pounds. (These particulars—rated load, maximum allowable load, relief valve setting, etc.—are listed in the applicable Instructions Manual.)

Assume that a load in excess of the maximum allowable load is placed on the actuator. During the DOWN stroke of the pump piston, the pressure in the system will increase to the point that it overcomes the spring tension of the relief valve. This forces the ball of the relief valve off its seat and allows the fluid to flow from the pump cylinder back to thé reservoir. Thus, the relief valve prevents excessive pressure buildup which could cause damage to the system. Hence, the term safety valve.

The maintenance of hand pumps includes frequent inspections for leakage, general condition, and efficiency of operation. Removal, replacement, and operational check of hand pumps should correspond to the procedures recommended in the specific Instructions Manual.

POWER PUMPS.—Power-driven hydraulic pumps are divided into two displacement

ypes—constant (positive) displacement and ariable (nonpositive) displacement. A constant lisplacement pump is one that displaces or deivers a constant fluid output for any given rotaional speed. For example, assume that a pump s designed to deliver 3 gallons of fluid per minite at a speed of 2,800 revolutions per minute. As long as the pump runs at this speed, it will continue to deliver at that rate, regardless of he pressure in the system. For this reason, vhen the constant displacement pump is used in closed-center system, a pressure regulator or inloading valve must be incorporated in the sysem. However, a regulator or unloading valve s not required when a constant displacement ump is used in an open-center system.

NOTE: Open-center and closed-center sysems are discussed in chapter 14.

A variable displacement pump has a fluid utput that varies to meet the demands of the ystem. For example, a pump might be designed o maintain system pressure at 3,000 psi by arying the fluid output from 0 to 7 gallons per ninute. When this type of pump is used, no ressure regulator or unloading valve is needed, ince no pumping action takes place except when ressure is required in the system. Both the onstant and the variable displacement pumps re found in ground support equipment.

As previously mentioned, the gear pump and everal types of reciprocating power pumps are sed in ground support equipment. These pumps re driven by electric motors or, through gearoxes, by gasoline or diesel engines. Gear umps are constant displacement and may utiize the spur gear, helical gear, or herringbone ear. Spur gears are most commonly used in ne gear pumps found in the hydraulic systems f ground support equipment. Gear pumps are escribed in detail in Fluid Power, NavPers 6193-B, and are therefore not covered in this nanual.

The reciprocating power pumps used in round support equipment are usually of the xial piston type. Axial piston pumps are availble in either the constant displacement type or ne variable displacement type. Both types are ound in ground support equipment. Two models f axial piston pumps—one constant displaceient and one variable displacement—are decribed in the following paragraphs.

NOTE: The general operation of axial piston umps is covered in Fluid Power, which should e studied in conjunction with the following disussion.

A cutaway view of a constant displacement axial piston pump of the type used in support equipment is illustrated in figure 13-4. This type is referred to as a Stratopower pump and is one of the three different types of pumps used in the hydraulic system of weapons loaders. A gear pump and a double-action hand pump are also utilized in these systems. (Weapons loader hydraulic systems are discussed in chapter 14.)

The model of Stratopower pump discussed here contains nine pistons. It is rated at 1,500 psi and is capable of delivering 3.25 gallons of fluid per minute at 1,500 rpm. A shear section is provided in the pump drive shaft to prevent damage from overload.

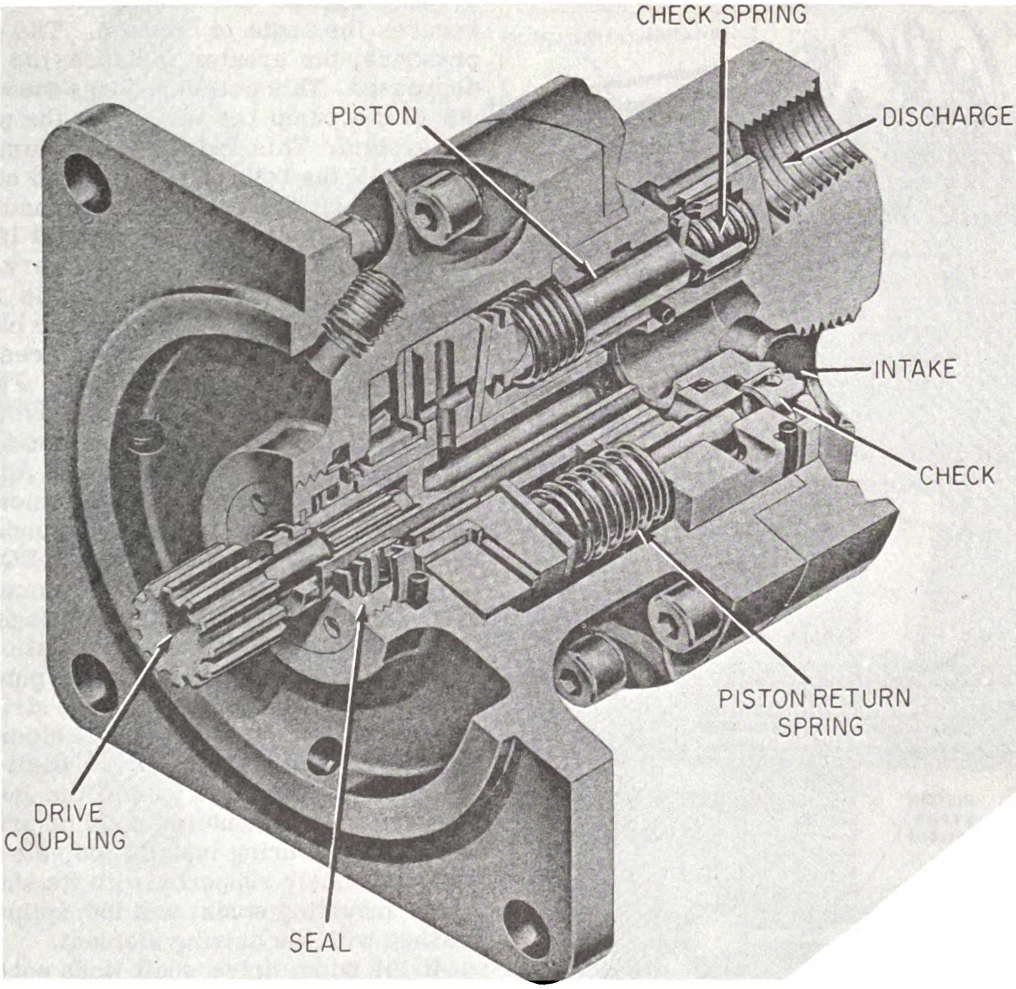
Two major functions are performed by the internal parts of the pump. These functions are mechanical drive and fluid displacement.

The mechanical drive mechanism is shown in figure 13-5. Piston motion is caused by the drive cam displacing each piston the full height of the drive cam each revolution of the drive shaft. By coupling the ring of pistons with a nutating (wobble) plate supported by a fixed center pivot, the pistons are held in constant contact with the cam face. As the drive cam depresses one side of the nutating plate (as pistons are advanced), the other side of the nutating plate is withdrawn an equal amount, moving the pistons with it. The two creep plates are provided to decrease wear on the revolving cam.

A schematic diagram of the displacement of fluid is shown in figure 13-6. Fluid is displaced by axial motion of the pistons. As each piston advances in its respective cylinder block bore, pressure opens the check and a quantity of fluid is forced past. Combined back pressure and check spring pressure closes the check when the piston advances to its foremost position. The low-pressure area occurring in the cylinder during the piston return causes reservoir fluid to flow from the intake loading groove in the cylinder.

A fluid flow diagram of the Stratopower pump is illustrated in figure 13-7. Fluid enters the intake port and is discharged to the high-pressure side past the pump checks by the reciprocating motion of the pistons. Fluid is circulated through the back of the pump for cooling and lubricating purposes by the centrifugal action of the drive cam.

Figure 13-8 illustrates a variable displacement axial piston pump of the type used on several models of hydraulic test stands. Like the



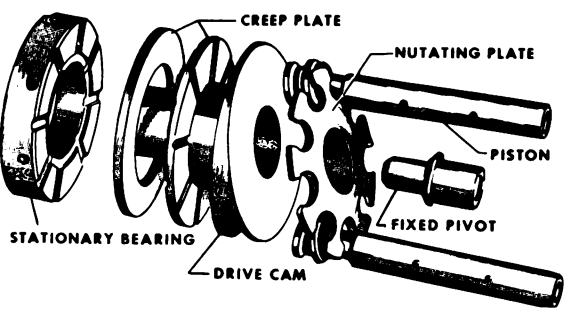
FP.132

Figure 13-4.—Cutaway view of Stratopower hydraulic pump.

hand pump and the constant displacement pump previously described, the variable displacement pump uses the piston and cylinder to create flow. At a given speed of pump rotation, the amount of fluid flow depends upon the distance of piston travel. In both the constant and variable displacement pumps, the piston travel depends upon the angle of the drive cam. In the constant displacement pump this angle is fixed; therefore, this pump delivers a fixed volume of fluid during revolution of the pump mechanism. In the variable displacement pump illustrated in figure 13-8, the angle of the cam is controlled by moving the hanger up and down. Therefore, the volume of fluid flow can be adjusted to meet the demands of the system.

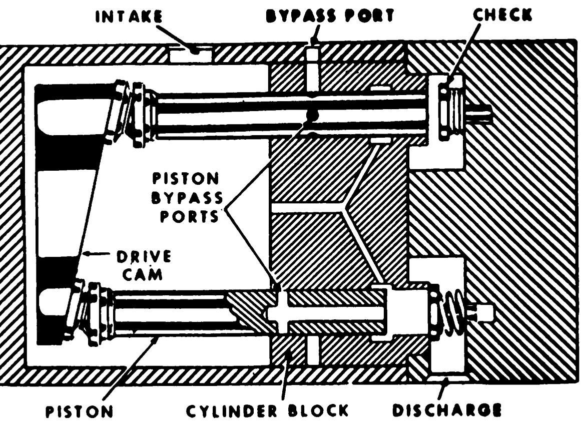
With the hanger in the UP position, as shown in figure 13-8, the length of each piston stroke is the greatest. Therefore, the pump delivers the maximum amount of flow per revolution when the hanger is in this position. As the hanger moves downward, the length of the piston stroke decreases, thus reducing the volume of flow proportionally for each revolution of the pump.

The movement of the hanger is controlled with a pressure compensator handwheel control. This is a combination of two pump controls—the



FP.133

Figure 13-5.—Mechanical drive—Stratopower pump.



FP.134

Figure 13-6.—Fluid displacement—Stratopower pump.

ndwheel and the pressure compensator. This it is mounted on the pump above the hanger, d the controls are attached to the hanger by echanical linkage and a hydraulic piston. Adstment of the handwheel limits the distance which the hanger can move upward, thus niting the maximum fluid output of the pump. wever, the hanger can still move downward.

The pressure compensator receives a flow fluid through a small line from the outlet side the pump. As system pressure increases, e valve in the compensator is forced open. e flow of fluid from the compensator valve is en applied directly against a piston which presses against the hanger mechanism. This reduces the angle of the cam. The greater the pressure, the greater distance the hanger is depressed. This action reduces the volume output of the pump but maintains the pressure in the system. This reduction in volume will continue until the bottom stop (located on the opposite side of the pump) is encountered. This minimum stop is used only when it is not desirable to go to zero volume delivery. In most pumps, a small volume of flow is required at all times for the lubrication of the pump.

Both the handwheel and the pressure compensator are manually adjusted. First, adjust the handwheel control for the maximum volume required; then adjust the compensator valve at the maximum pressure required. Additional information concerning the adjustment of these controls is covered in chapter 14 under the section entitled HYDRAULIC TEST EQUIPMENT.

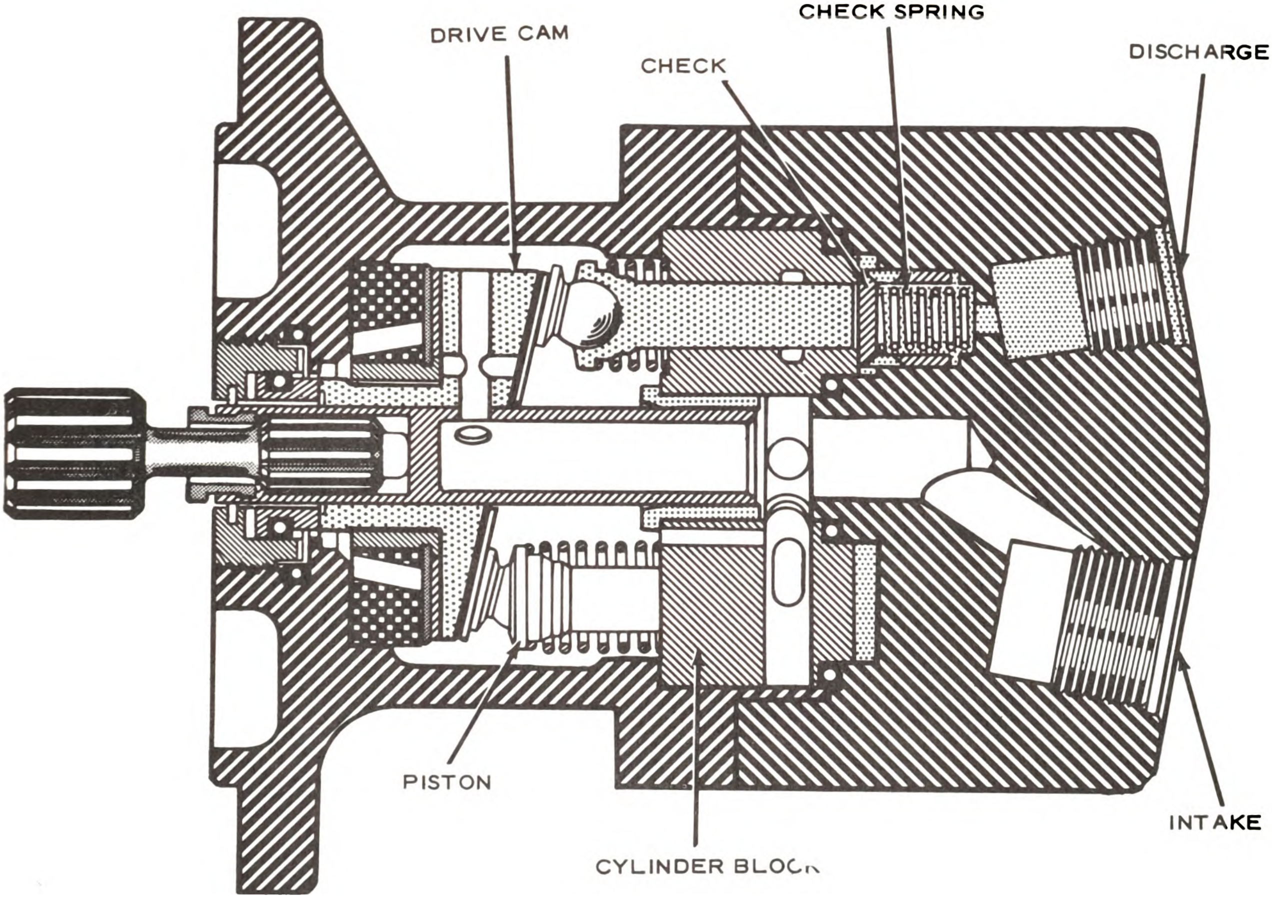
The maintenance of power pumps includes inspection for leaks and loose fittings, operation inspections, removal and installation, and test and repair. When removing a pump, always maintain its alignment until the drive shaft is fully withdrawn from the driving element. Never pick up a pump by the drive shaft extension.

Before installing a pump, the pump and its attached hose assemblies must be primed (filled with fluid). During installation, the pump must be continuously supported with its shaft parallel to the mounting studs, and the splines must be meshed with the driving element.

If the pump drive shaft does not engage the driving element, preventing the pump from sliding into place, the drive shaft should be manually rotated until the two splined drive shafts mate.

Like all component repair, the repair of hydraulic pumps depends upon the extent of repair and the availability of replacement parts, tools, equipment, and qualified personnel. The applicable Repair and Overhaul Instructions Manual should be consulted for the correct procedures to be followed in the repair and test of hydraulic pumps.

New, repaired, and overhauled pumps should be checked on a hydraulic component test bench before installation in a system. Also, some pumps require a break-in period after certain parts are replaced. In addition, defective pumps should be checked on the test stand to determine the cause of malfunctions. The applicable Instructions Manual should be consulted for the correct specifications that must be met during



FP.135

Figure 13-7.—Fluid flow—Stratopower pump.

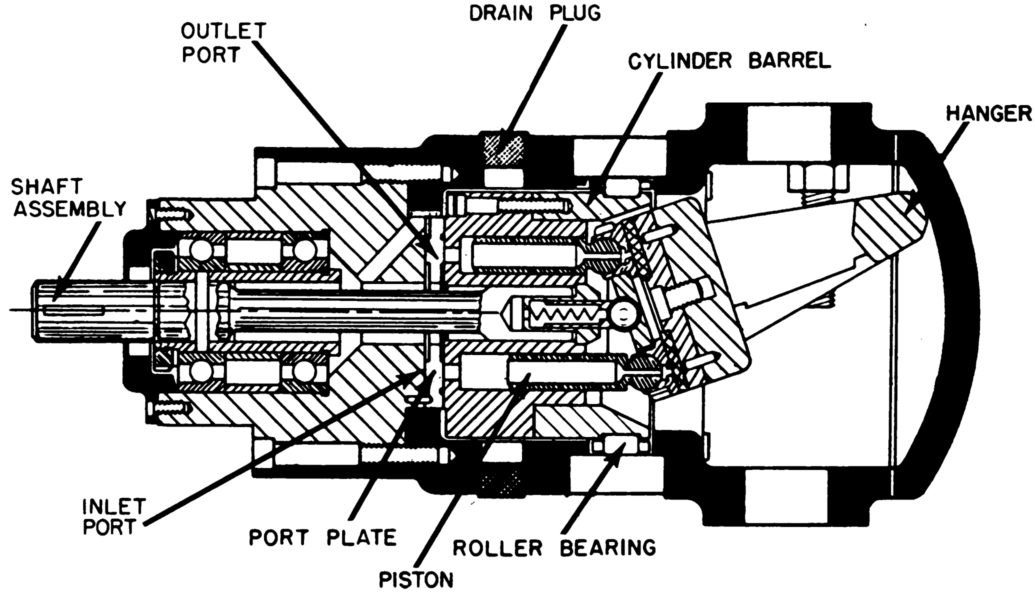
the test. These include inlet and outlet pressures and volume output at various speeds of the pump.

Figure 13-9 illustrates a test setup for the Stratopower hydraulic pump, previously described. Similar test setups may be used for the different types of hydraulic pumps.

Table 13-1 lists troubles which may be experienced with the pump during testing. The table lists the trouble, probable cause, remedy, and four classifications of corrective action. Diligent use of such troubleshooting charts will save many unnecessary maintenance hours.

As stated in several places in this manual, all maintenance functions performed on support equipment are not considered complete until they have been recorded on the appropriate source document. Parts (A), (B), and (C) of figure 13-10 illustrate the documentation of copies 1 and 3 of a multicopy Maintenance Action Form (MAF) for the removal, replacement, and repair of a hydraulic pump. Documentation for any repairable component would be similar. Military Requirements for Petty Officer 3 & 2, NavPers 10056 (Series), and OpNav Instruction 4790.2 (Series) should be consulted for detailed instructions concerning the information required in each block, the use and disposition of each copy, etc.

In the following discussion, assume that an Aero 47A weapons loader is inoperative because hydraulic pressure cannot be built up in the



AS.709

Figure 13-8.—Variable displacement axial piston hydraulic pump.

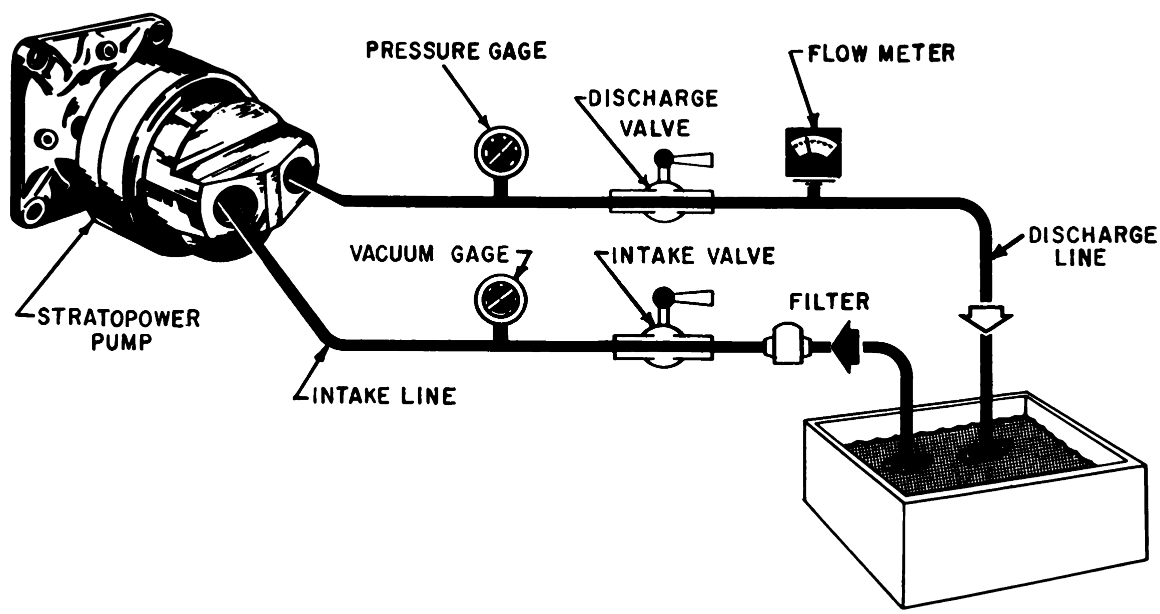


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Figure 13-9.—Test setup for Stratopower hydraulic pump.

Table 13-1.—Troubleshooting chart—Stratopower pump.

Trouble	Probable cause	Remedy	Type*
COMPLETE LOSS OF CAPACITY	Reservoir supply low	Replenish reservoir	1
	Air leak in intake lines or fittings	Check lines and fittings	1
	Intake line plugged	Disconnect line and remove obstruction	1
	Broken drive coupling	Remove and replace	2
PARTIAL LOSS OF CAPACITY	Reservoir supply low	Replenish reservoir	1
	Air leak in intake lines or fittings	Check lines and fittings	1
	Intake line plugged	Disconnect line and remove obstruction	1
	Air leak through shaft seal	Rework seal surfaces or replace	3
	Fouled or improperly seating pump check	Flush pump. If ineffective, disassemble and inspect checks and seats. Replace damaged or worn checks. Relap cylinder block face if necessary	4
	Damaged piston spring	Replace piston spring	4
	Worn or scored piston assemblies	Replace piston assemblies	4
	Worn or scored cylinder block	Replace cylinder block and piston assemblies	4
EXCESSIVE PULSATION	Reservoir supply low	Replenish reservoir	1
	Air leak in intake line or fittings	Check line and fittings	1
	Air leak in shaft seal	Replace shaft seal or rework damaged seal face	3
	Damaged check	Replace check	4
	Damaged piston spring	Replace piston spring	4
EXCESSIVE HEATING	Complete or partial failure of hydraulic fluid supply	Refer to complete or partial loss of capacity	

Table 13-1.—Troubleshooting chart—Stratopower pump—Continued.

Trouble	Probable cause	Remedy	Type*
COVER JOINT LEAKAGE	Damaged cylinder block O-ring	Replace O-ring	4
	Scratches or roughening of the internal cover surface	Rework cover to a smooth finish	4
	Scored housing near cover joint	Replace housing assembly	4
LEAKAGE AT SHAFT SEAL	Mismating sealing surfaces	Remove seal and check sealing surface alignment	3
	Damaged sealing surfaces	Remove seal and relap to a plane surface	3
	Defective O-rings	Remove seal and replace O-rings	3
	Damaged seal spring	Remove seal and replace spring	3

*Type of corrective action required. (1) Corrective action to be taken external of the pump. (2) Corrective action to the pump which can be taken without removing the pump from the test stand. (3) Repair requiring only a partial disassembly of the pump. (4) Malfunctioning requiring a complete disassembly of the pump.

accumulator circuit. After troubleshooting the system, it is found that the piston type hydraulic pump is defective. Therefore, the pump is removed and replaced with a new or repaired one received from supply. The complete documentation of this action is shown on copy 1 of the multicopy MAF illustrated in figure 13-10 (A).

Only a portion of the information entered in copy 1 of the multicopy MAF carbons through to the remaining copies. Figure 13-10 (B) shows that portion of copy 3 as it arrives in the component repair work center with the defective hydraulic pump. Notice that material screening has made additional entries in block 30.

Upon disassembly of the pump, it is found that one of the piston springs is broken. After replacing the broken spring with a new one received from supply, the pump is reassembled. Figure 13-10 (C) shows the completed documentation of copy 3 after the repair.

As indicated in the preceding discussion, supply plays an important role in the maintenance effort. In addition to providing parts and components and screening defective components for disposition, supply also provides the tools, material, and equipment required by the maintenance activity. The timely provision of these items requires coordination between the maintenance and supply activities. Therefore, the ASH should be familiar with the purpose and responsibilities of the local supply supporting activity.

Each maintenance activity has one point of contact with the supporting supply activity. This single contact point is the Supply Support Center (SSC), which responds to all material requirements of the maintenance organization. The SSC is an internal element of the local supply department at the division level and is responsible to the supply officer. The SSC is usually physically located adjacent to the maintenance area for improved maintenance and coordination.

The SSC is divided into two sections—Supply Response Section (SRS) and Component Control Section (CCS)—and is responsible for the following functions:

MAINTENANCE ACTION FORM (MULTI)
OPNAV FORM 4790/41 (10-69) S/N-0107-770-4500

1. JOB CONTROL NUMBER ORG.	DATE	SER	SUF	2. TYPE EQUIP.	3. BU/SER NO	4. ACTION ORG.	5. WORK CENTER	6. MAINT. LEVEL	7. ACTION DATE
P9C	1216	054		GMFC	000648	P9C	920	☐ 1 ORG. ☑ 2 INT. ☐ 3 DEP.	1216

8. WORK UNIT CODE	9. WHEN DISCD	10. TYPE MAINT.	11. ACTION TAKEN	12. MAL	13. ITEMS PROC.	14. MAN HRS.	15. EMT	16.
44AA1	C	B	R	037	1	4 0	2 0	

20. REMOVED ITEM		21. INSTALLED ITEM	
.1 MFGR 90166	.2 SERIAL NUMBER 55414	.1 MFGR 90166	.2 SERIAL NO. 55475
.3 PART NUMBER 67P300	.4 TIME/CYCLES A0330	.3 PART NUMBER 67P300	.4 TIME/CYCLES A0330

B. DISCREPANCY	C. CORRECTIVE ACTION
UNABLE TO BUILD UP PRESSURE IN ACCUMULATOR CIRCUIT.	REMOVED AND REPLACED HYDRAULIC PISTON PUMP

D. ENTRIES REQUIRED		SIGNATURE	E. CORRECTED BY	F. INSPECTED BY	G. SUPERVISOR
CONFIGURATION	☐ YES ☑ NO		R. Younce ASH2	A. Carter AS1	E. E. Brown ASC5
LOG	☐ YES ☑ NO				
ACCESS RECORD	☐ YES ☑ NO				

30. REPAIR CYCLE DATA

	DATE		DATE
1. REMOVED	1216	5. AWP	
2. RECEIVED MATL. CONTROL		6. OFF AWP	
3. WORK STARTED		7. TO AWP	
4. COMPLETED		8. OFF AWP	
RFI ☐ B COND ☐ R/S ☐		9.	
		0.	

H. PCN	PRIORITY	DATE DUE IN	OUT

40. FAILED MATERIAL

.1 ACT TKN	.2 MAL	.3 QTY	.4 MFGR	.5 PART NUMBER/REF. SYMBOL

J. ACCUMULATED HOURS

NAME/SHIFT	DATE	MAN HRS.	EMT
TOTAL			

K. REQUIRED MATERIAL

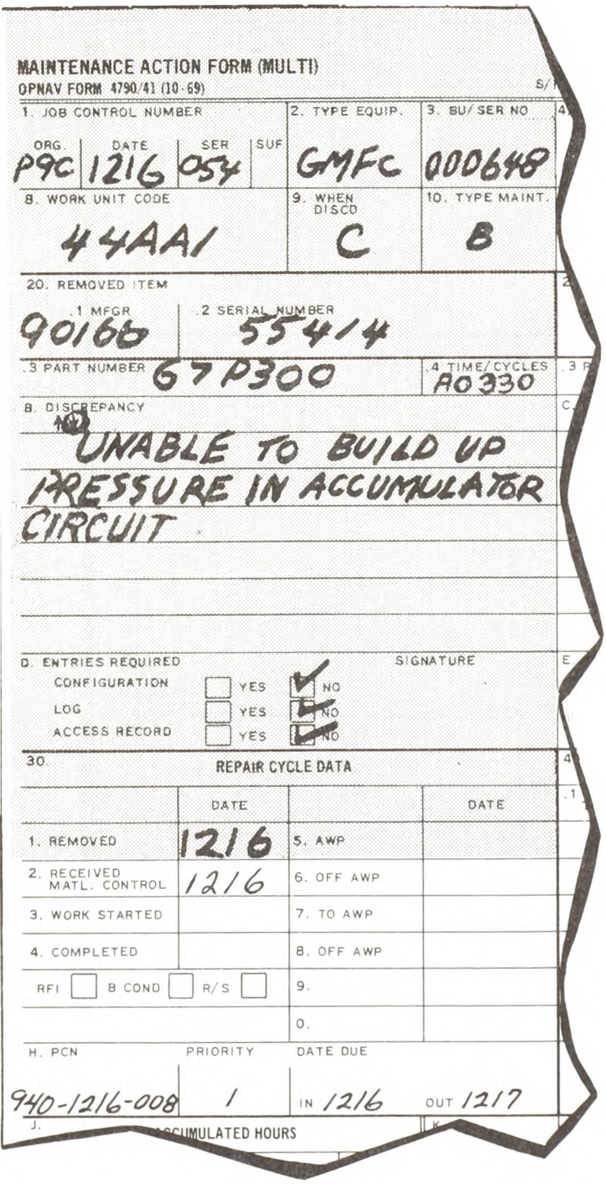
REQ. NO.	MFGR	PART NUMBER	QTY	PRI	DATE/TIME ORD	DATE/TIME REC	AWP
7926	90166	67P300	1	1	0900 1216	1000 1216	

COPY 1

(A)

AS.711

Figure 13-10.—Multicopy Maintenance Action Form (MAF) documentation. (A) Copy 1—removal and replacement of repairable component (hydraulic pump).



MAINTENANCE ACTION FORM (MULTI)
OPNAV FORM 4790/41 (10-69)

1. JOB CONTROL NUMBER (ORG. / DATE / SER / SUF)	2. TYPE EQUIP.	3. BU/SER NO
P9C / 1216 / 054 /	GMFC	000648
8. WORK UNIT CODE	9. WHEN DISCD	10. TYPE MAINT.
44AA1	C	B

20. REMOVED ITEM

.1 MFGR	.2 SERIAL NUMBER
90166	55414

.3 PART NUMBER 67P300 — .4 TIME/CYCLES A0330

B. DISCREPANCY
UNABLE TO BUILD UP PRESSURE IN ACCUMULATOR CIRCUIT

D. ENTRIES REQUIRED — SIGNATURE

	YES	NO
CONFIGURATION	☐	☑
LOG	☐	☑
ACCESS RECORD	☐	☑

30. REPAIR CYCLE DATA

	DATE		DATE
1. REMOVED	1216	5. AWP	
2. RECEIVED MATL. CONTROL	1216	6. OFF AWP	
3. WORK STARTED		7. TO AWP	
4. COMPLETED		8. OFF AWP	
RFI ☐ B COND ☐ R/S ☐		9.	
		0.	

H. PCN	PRIORITY	DATE DUE	
940-1216-008	1	IN 1216	OUT 1217

J. ACCUMULATED HOURS

(B)

AS.712

Figure 13-10.—Multicopy Maintenance Action Form (MAF) documentation—Continued. (B) Copy 3—repairable component (hydraulic pump) to be repaired.

1. Receives requirements for parts and materials to support aviation maintenance.

2. Performs technical research and prepares supply documents.

3. Delivers parts and materials to customers.

4. Accounts for repairable components due from both Organizational and Intermediate maintenance activities.

5. Maintains rotatable pools and provides pool listings.

NOTE: Rotatable pool material consists of selected repairable ready-for-issue (RFI) items. Items maintained in the pool are capable of being repaired by the local Intermediate maintenance activity. The range of rotatable pool items will normally be limited to components that must be available immediately to shorten overhaul and repair time. Replacement components are supplied from the pool. After the defective components are repaired by the AIMD to an RFI condition, they are returned to the rotatable pool to replace the components previously issued. For example, consider the hydraulic pump used to illustrate the documentation of a MAF (fig. 13-10) as a rotatable pool item. To shorten the repair time for the weapons loader, the replacement pump is provided from the rotatable pool. After the defective pump is repaired, it is turned in to the rotatable pool.

6. Establishes, maintains, and replenishes all preexpended bins and provides preexpended listings.

NOTE: Preexpended bins contain common repair parts (nuts, bolts, washers, lubricants, etc.) that are considered to be high in usage and low in unit cost. These items are expended from Supply Department stock records and related financial accounts. These bins are replenished from stocks in the retail outlet that supports the shop in which the preexpended bin is located.

7. Initiates local repair requests and originates and controls inter AIMD repair requests.

8. Originates and controls customer service requests in conjunction with the cognizant Naval Air Systems Command Representative.

9. Initiates and maintains material planning procedures for support of fleet maintenance.

The SSC is manned and open for business consistent with the operating hours of the maintenance organization supported by the SSC. If maintenance is being performed 24 hours a day, supply support will be available 24 hours a day. The number of personnel manning the SSC during periods other than normal working hours is such that supply support is assured for the maintenance being performed.

MAINTENANCE ACTION FORM (MULTI)
OPNAV FORM 4790/41 (10-69)   S/N-0107-770-4500

1. JOB CONTROL NUMBER (ORG. / DATE / SER / SUF)	2. TYPE EQUIP.	3. BU/SER NO	4. ACTION ORG.	5. WORK CENTER	6. MAINT. LEVEL (1 ORG. / 2 INT. / 3 DEP.)	7. ACTION DATE
P9C 1216 054	GMFC	000648	P9C	940	2 INT. ✓	1216

8. WORK UNIT CODE	9. WHEN DISCD	10. TYPE MAINT.	11. ACTION TAKEN	12. MAL	13. ITEMS PROC.	14. MAN HRS.	15. EMT	16.
44AA1	C	B	C	374	1	6 0	6 0	

20. REMOVED ITEM		21. INSTALLED ITEM	
.1 MFGR 90166	.2 SERIAL NUMBER 55414	.1 MFGR	.2 SERIAL NO.
.3 PART NUMBER 67P300	.4 TIME/CYCLES A0 330	.3 PART NUMBER	.4 TIME/CYCLES

B. DISCREPANCY	C. CORRECTIVE ACTION
4 UNABLE TO BUILD UP PRESSURE IN ACCUMULATOR CIRCUIT	REPLACED BROKEN PISTON SPRING.

D. ENTRIES REQUIRED		SIGNATURE	E. CORRECTED BY	F. INSPECTED BY	G. SUPERVISOR
CONFIGURATION	YES ☐ NO ✓		C. F. Meyers ASH2	G. L. Tokken AS1	F. D. Davis ASCS
LOG	YES ☐ NO ✓				
ACCESS RECORD	YES ☐ NO ✓				

30 REPAIR CYCLE DATA

	DATE		DATE
1. REMOVED	1216	5. AWP	
2. RECEIVED MATL. CONTROL	1216	6. OFF AWP	
3. WORK STARTED	1217	7. TO AWP	
4. COMPLETED	1217	8. OFF AWP	
RFI ☐ B COND ☐ R/S ☐		9.	
		0.	

H. PCN	PRIORITY	DATE DUE	
940-1216-008	1	IN 1216	OUT 1217

40. FAILED MATERIAL

.1 ACT TKN	.2 MAL	.3 QTY	.4 MFGR	.5 PART NUMBER/REF. SYMBOL
R	070	1	90166	67A1365-1

J. ACCUMULATED HOURS

NAME/SHIFT	DATE	MAN HRS.	EMT
DAY	1217	6.0	6.0
TOTAL		6.0	6.0

K. REQUIRED MATERIAL

REQ. NO.	MFGR	PART NUMBER	QTY	PRI	DATE/TIME ORD	DATE/TIME REC	AWP
	90166	67A1365-1	1	1	0900 1217	0930 1217	

(C)   COPY 3

AS.713

Figure 13-10.—Multicopy Maintenance Action Form (MAF) documentation—Continued. (C) Copy 3—repair of component (hydraulic pump).

FILTERS

A filter is a device whose primary function is the retention, by some porous medium, of insoluble contaminants from the hydraulic fluid. The porous medium is the screening or filtering material that allows oil to flow through it but traps solid particles. The porous device which performs the actual process of filtration is referred to as the filter element.

Practically all the particle contaminants found in usable hydraulic fluid can be removed by filtration. The degree of filtration is dependent upon the acceptance level desired.

The hydraulic systems of many items of support equipment incorporate 3-micron absolute filtration. (Micron is defined later.) This is especially true of aircraft hydraulic servicing and test equipment. (At the time of this writing, some test stands only filter to 10 microns but are in the process of being changed over to filter 3 microns.) These filters are intended primarily to safeguard the operation of certain critical units and adequately control the particle contaminants which are generated by the wear and tear of the components in the system. They are not, however, adequate to handle the injection of large particles of contaminants from sources outside the system. (See chapter 14 for additional information concerning the control of fluid contamination.)

Filters are absolutely necessary to insure proper operation of the system and longer service from the pumps, valves, and other components of the system.

In hydraulic systems, filters may be located within the reservoir, in the pressure line, in the return line, or in any other location where they are needed to safeguard the system against foreign particles.

For many of the same reasons, filters are also required in pneumatic systems. In these systems, filters are located in the pressure line and in the compressor intake. In addition, some means of removing the moisture from the air must be incorporated in pneumatic systems.

Filter elements are usually made either of paper or of metal. The paper (cellulose) elements are used mostly in low-pressure applications and are thrown away when removed. Metal elements are used in both high- and low-pressure applications and may be either disposable or cleanable. In addition to these types, the wire mesh filter, which is usually referred to as a strainer, is frequently used in the reservoir of hydraulic systems. (See fig. 13-2.)

Micronic Type

Micronic, a term derived from the word micron, could be used to describe any filter element. However, through usage, this term has become associated with a specific filter with a filtering element made of specially treated cellulose paper.

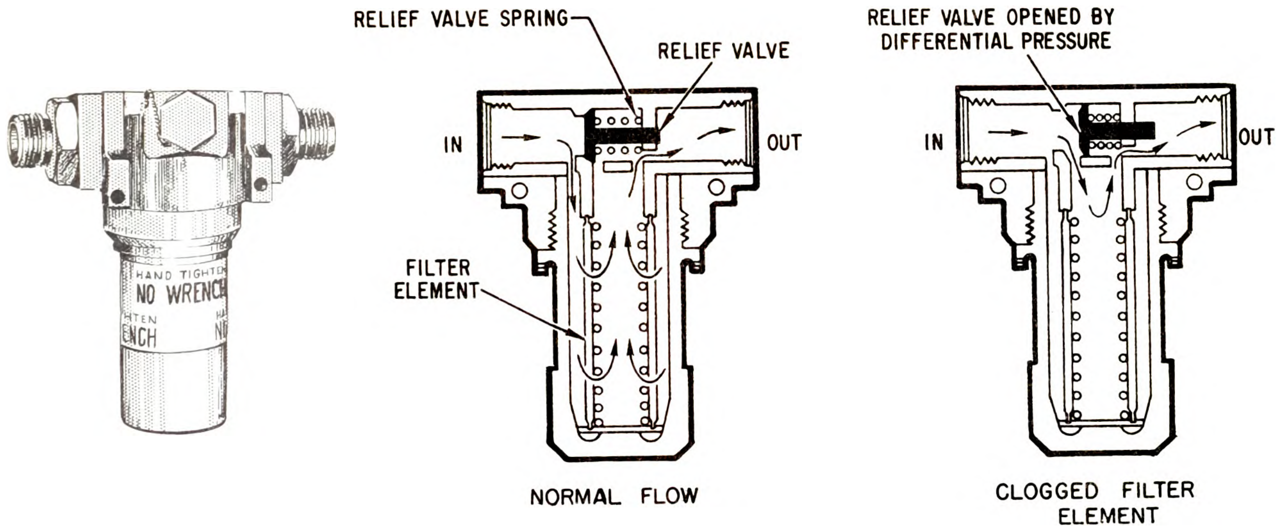
A typical micronic type filter is shown in figure 13-11. This type filter is designed to remove 99 percent of all particles 10 microns (0.000394 inch) in diameter, and larger. To define this capability in meaningful terms: If 100 particles measuring 0.000394 inch in cross section were dropped into pure hydraulic fluid, a 10-micron filter will intercept 99 percent of these in one pass. A 40-micron particle is regarded to be the smallest which can be seen without magnification. A micronic filter assembly contains a replaceable micronic filter element and, in most cases, an integral pressure differential bypass valve.

If the micronic filter element is allowed to become clogged, the pressure differential bypass valve will open, allowing fluid to bypass the filter element when a certain predetermined differential exists.

The replaceable element is made of specially treated cellulose paper, formed in vertical convolutions (wrinkles). The filter shown in figure 13-11 has an external thread machined on the outside and top of the filter bowl which fits in the underside of the body. A groove machined around the base of the threads provides the location for packing between the filter bowl and body assembly.

Fluid enters the filter through the inlet port in the body and flows around the element inside the filter bowl. Filtering takes place as the fluid passes through the filtering element at the hollow core, leaving the dirt and impurities on the outside of the filter element. Filtered fluid then flows from the hollow core to the outlet port in the body and into the system.

The bypass pressure relief valve in the body allows fluid to bypass the filter element and pass directly through the outlet port in case the filter element becomes clogged. In most filters of this type, the relief valve is set to open if the pressure differential exceeds 50 psi. In other words, if the pressure at the filter inlet port



AM.760

Figure 13-11.—Micronic filter.

was 1,500 psi, and the pressure at the outlet port dropped below 1,450 psi, the relief valve would open.

NOTE: Some filters of this type are not equipped with a bypass pressure relief valve.

Micronic filter elements are normally replaced with new filter elements at regular intervals. These intervals are specified in the applicable Instructions Manuals and Maintenance Requirements Cards. The following procedure for removing and replacing filter elements is typical of almost all systems:

1. Relieve system pressure.
2. Cut lockwire and remove the filter case (bowl) from the filter head (body).
3. Unscrew and remove the filter case, using a slight rocking and downward pull on the case after the case threads are free from the filter.
4. The filter element shown in figure 13-12 is removed from the case by extracting the retaining ring and removing the filter element.
5. After insuring that a replacement filter element is available, the filter element should be cut, as indicated in figure 13-12, and inspected internally for evidence of system contamination.

NOTE: At the time of filter element replacement one should never try to gage its condition by visual inspection alone. The naked eye cannot detect particles smaller than 40 microns. Consequently, the element could be heavily contaminated with 10- to 20-micron particles, and the only way the condition of this element can be determined is by performing a back pressure flow check on a test stand.

CAUTION: When selecting a new filter element, do not be guided by its appearance and physical dimensions alone. Always go by the part number. Many elements look identical but will disintegrate if installed in the wrong type of fluid and cause havoc to a good hydraulic system.

6. Prior to installation of the replacement element, the filter head and filter case must be cleaned and inspected for damage. All damaged parts must be replaced.
7. Replace all O-ring seals.
8. Fill the filter case with new MIL-H-5605-B fluid prior to installing the case to the filter head. Filling the case and filter element with new fluid helps to eliminate the injection of air into the hydraulic system.
9. Install the filter element in its case and screw the case into the filter head; correct torque is usually handtight or handtight plus 1/8 turn. Always check the specific Instructions Manual.
10. Pressurize the system and inspect the filter assembly for leaks. If it is found satisfactory, replace the lockwire between the filter case and the head assembly.

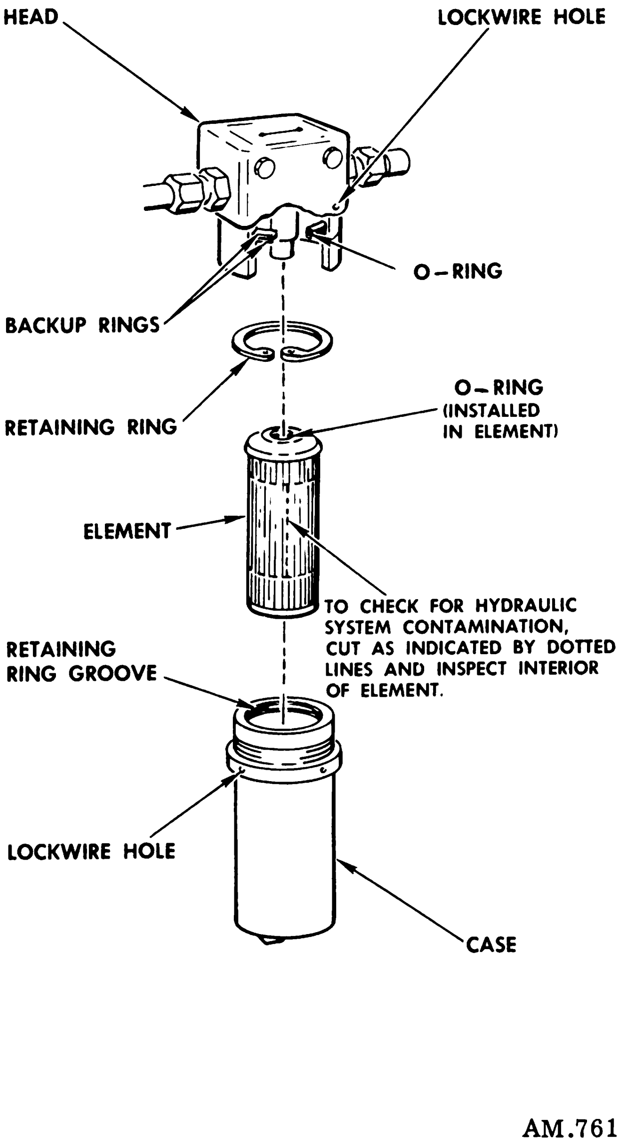


Figure 13-12.—Micronic filter assembly.

Metal Type

The two most common types of metal filter elements are the sintered bronze and the stainless steel. The sintered bronze element consists of minute bronze balls joined together as one solid piece, but still remains porous. The process of joining the balls together is known as the sintered process. Like the micronic filter described previously, filters utilizing the sintered bronze elements are equipped with a bypass valve. If the element becomes clogged, the bypass valve will open, allowing the fluid to bypass the filter element when a predetermined pressure differential exists.

The sintered bronze element can be cleaned, tested, and reused several times. Refer to the applicable technical manual for cleaning procedures.

The stainless steel filter element may be of corrugated, sintered, or mesh construction. One type of stainless steel filter incorporates both a differential pressure indicator and a bypass valve within the filter head. (See fig. 13-13.) The second type incorporates the differential pressure indicator only.

The differential pressure indicator operates under the principle of difference in pressure entering the element and pressure after it leaves the element. As contaminating particles collect on the outside of the filter element, the differential pressure across the element increases. When this increased pressure reaches a specific value (70 ± 10 psi in the filter illustrated in figure 13-13), inlet pressure forces the spring-loaded magnetic piston downward, breaking the magnetic attachment between the indicator button and the magnetic piston. This allows the red indicator to pop out, signifying that the element must be cleaned. In some systems, for example hydraulic test stands, this indication is connected electrically to a warning light on the control panel.

Due to the increase in fluid viscosity at low temperatures and the possibility of a false contamination indication, a low-temperature lockout of the differential pressure indicator prevents actuation of the indicator at low temperatures.

NOTE: Filter elements used in connection with a pressure indicator are not normally removed or replaced until the indicator is actuated. This decreases the possibility of system contamination from outside sources due to unnecessary handling.

Filters of this type which contain the differential pressure indicator only are referred to as nonbypassing. If the filter element is not replaced when the indicator signifies, the filter element will continue to collect foreign particles. The differential pressure between the inlet and outlet ports will increase; however, fluid will not bypass the element.

If this condition continues, it could eventually starve the system and prevent the operation of certain actuating units. In many instances, this could result in damage to equipment and injury to personnel. As a result, filters containing

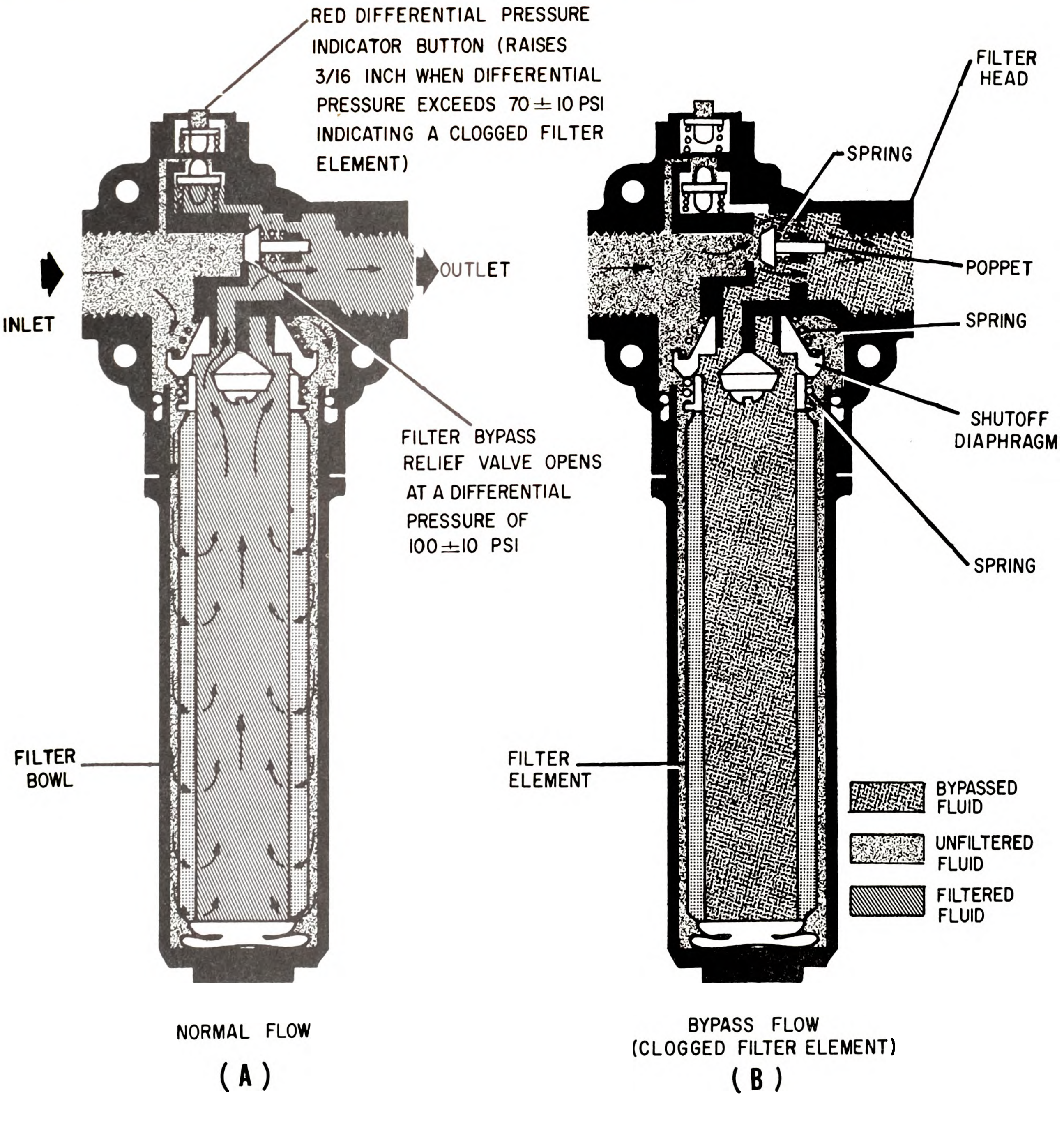


Figure 13 13.—Stainless steel hydraulic filter featuring the differential pressure indicator and bypass valve.

both the differential pressure indicator and the bypass valve are used in these critical systems. If the element in this type filter is not replaced when the indicator signifies, the element will continue to collect foreign particles. The pressure differential between the inlet and

outlet ports will increase until the bypass valve opens (100 ± 10 psi in the filter shown in figure 13-13). Fluid is then directed through the filter bypass, as shown in view (B).

Water Elimination

In addition to filters for the removal of solid foreign particles, pneumatic systems must be provided with a means to remove moisture from the air. The atmosphere contains various amounts of moisture, depending upon the geographic location and the existing weather conditions. During the compression of this air, the moisture condenses. If left in the system, this condensation will accelerate rusting and corrosion of the components. In addition, some of the water will settle and collect in the low points of the distribution lines. When the temperature is below freezing, the water will freeze and cause the system to be inoperative.

The moisture separator and the chemical drier (dehydrator) are utilized in pneumatic systems to remove the moisture from the air. Moisture separators are used in conjunction with the intercoolers and aftercoolers and are usually located in the line between the compressor and the receiver. In a representative intercooler and aftercooler, the air flows through a series of pipes which are surrounded by flowing coolant, either water or air. Here, the compressed air is cooled and condensation occurs. The air is caused to flow through the separator in a circular path in which a large amount of the condensed water is thrown outward to the walls and falls to a collection chamber which is drained periodically.

Chemical driers are incorporated in some pneumatic systems. Their purpose is to absorb any moisture that may collect in the lines and other parts of the system. Each drier contains a cartridge which contains a moisture absorbing chemical. Additional information concerning chemical driers is contained in the last part of this chapter.

VALVES

A valve is a device which controls the flow or pressure of the fluid in a fluid power system. Valves are usually classified as to the type of control they provide. Valves which regulate the rate of flow are known as flow control valves, valves which regulate pressure are referred to as pressure control valves, and valves which direct a flow of fluid to and from an actuator are referred to as directional control valves. Directional control valves are also commonly known as transfer valves, selector valves, or control valves.

The operation of the various types of valves is covered in detail in Fluid Power, NavPers 16193-B. Some examples of flow control valves, pressure control valves, and directional flow valves which are found in the fluid power systems of support equipment are described in the following paragraphs.

Flow Control Valves

A typical example of a flow control valve is the ordinary water faucet. It is normally in the closed position, allowing no flow. It can be fully opened allowing a full flow, or the flow can be varied by turning the faucet handle clockwise or counterclockwise, which changes the opening of the valve.

Many of the flow control valves used in fluid power systems are similar to the water faucet. The valve element may be in the form of a plug, a gate, a disc, or a needle. The valve element seats against a valve seat in the closed position and blocks the flow of fluid. The plug, gate, and disc type valves are normally used as fully ON and fully OFF valves. The needle valve is usually used in the system where it is necessary to throttle (vary) the rate of flow.

Many flow control valves are operated manually, similar to the operation of the water faucet. For example, the release valve in the hydraulic jack system (discussed in chapter 14) is a flow control valve of this type. The release valve is closed during the raising operation, and is then opened during the lowering operation. The speed of the lowering operation depends upon the rate of flow of the fluid through the release valve which, in turn, depends upon the distance that the release valve is opened.

The restrictor is another type of flow control valve used in fluid power systems. Its purpose is to limit the speed of certain actuators. The two-way restrictor restricts the flow of fluid in both directions. This type of restrictor is a small valve containing a small orifice for the passage of fluid. The rate of flow through the valve is determined by the size of the orifice. In some restrictors the size of the orifice is fixed. Such restrictors are known as fixed restrictors. The size of the orifice in some

two-way restrictors may be adjusted. This type is referred to as a variable restrictor.

In some cases it is necessary to control the speed of certain actuators in only one direction. For example, the lift cylinder of a forklift (see chapter 14) requires full flow of fluid to raise a load. However, it is necessary to restrict the flow during the lowering of the load. This is often accomplished by incorporating a one-way restrictor in the UP line (the line containing system pressure during the lifting operation). The restrictor allows full flow during the lifting operation. During the lowering operation, this line provides for return flow from the actuator. The one-way restrictor restricts the flow of this return fluid, thus slowing down the speed of actuation during the lowering operation.

An example of a one-way restrictor is illustrated in figure 13-14. When the fluid flows from left to right, the pressure of the fluid overcomes spring tension and forces the cone to the open position. This action permits free flow through the valve. When the fluid flows from right to left, the cone is forced closed and the flow of fluid is restricted through the small orifice in the cone.

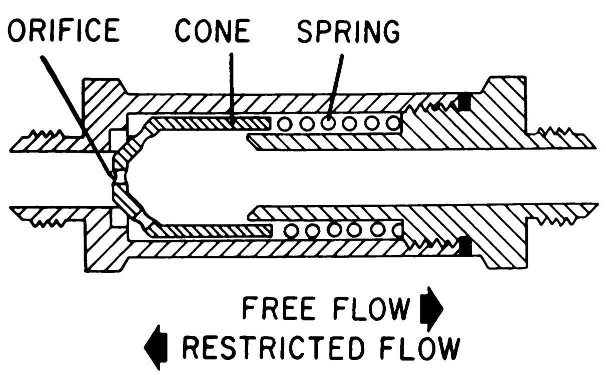


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Figure 13-14.—One way restrictor.

Flow regulators are found in the hydraulic systems of some types of support equipment. This type valve meters a constant flow regardless of variation in system pressure. It may be used to meter fluid out of a subsystem in a manner similar to the one-way restrictor described above, or it may be used to meter fluid into a subsystem.

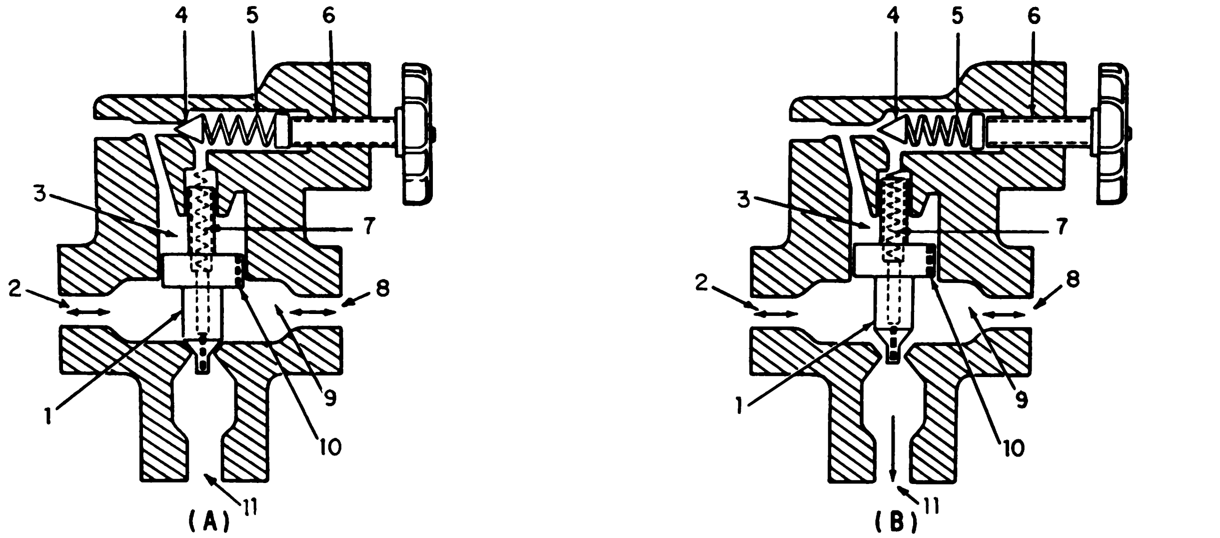
One type of flow regulator meters a constant volume of fluid into a subsystem and bypasses the remaining fluid to return or to another subsystem. This type regulator is sometimes referred to as a flow divider. However, it does not necessarily divide the flow into two equal volumes, which is the function of a flow equalizer. A combination of three flow dividers is used in the hydraulic system of the SD-1C/SD-1D spotting dolly. This system is described and illustrated in chapter 14.

Pressure Control Valves

The most common pressure control valve is the relief valve. The relief valve provides protection against overloading system components or limits the force which can be exerted by the actuator. One example of a relief valve was described and illustrated earlier in this chapter. (See fig. 13-3.) Many of the relief valves found in fluid power systems operate similar to this valve. A more complex relief valve is illustrated in figure 13-15. Relief valves of this type are utilized in hydraulic test stands.

View (A) of figure 13-15 shows the relief valve in the closed position, and view (B) shows the valve in the open position. In the closed position, fluid at system pressure flows through the inlet port (2 or 8), around piston (1), and out the outlet port. Inlet and outlet ports may be used interchangeably when the valve is mounted in the pressure line, or one port may be plugged when the valve is teed off the pressure line. By means of passage (10) in piston (1), fluid also flows into chamber (3) and acts on the pilot valve (4), which is held on its seat by spring (5). The force of spring (5) is regulated by the adjusting screw (6) and determines the pressure setting of the valve. Valve operation will not remain steady if the pilot valve (4) does not seat properly.

Piston (1) will remain in the closed position; that is, on its seat because of the tension of spring (7), as long as the pressure in chambers (3 and 9) remains equal. The piston, in this condition, is referred to as being in hydraulic balance. The piston will remain seated until the pressure in chamber (3) exceeds the equivalent force of spring (5). As soon as this occurs, the pilot valve (4) is forced off its seat and the pressure in chamber (3) is limited by the escape of fluid past this piston and down through the centrally drilled passage in piston (1) to the return port (11). When the pressure in chamber



1. Piston.
2. Pressure port (inlet or outlet).
3. Fluid chamber.
4. Pilot valve.
5. Spring.
6. Adjusting screw.
7. Spring.
8. Pressure port (inlet or outlet).
9. Fluid chamber.
10. Fluid passage.
11. Return to reservoir.

Figure 13-15.—Pilot-operated relief valve.

9) increases further until it is sufficient to vercome the pressure in chamber (3) and the orce of spring (7), it lifts piston (1) off its seat. 'his will allow fluid in chamber (9) to escape hrough the return port (11). In actual operaion, piston (1) will open just sufficiently to llow excess fluid to escape and will remain n this opened or throttled position as long as he resistance to fluid flow causing pressure uildup is present in the system.

When system pressure decreases to the preetting of the pilot valve, the tension of spring 5) forces the pilot valve (4) on its seat. Beause of the passage (10) in piston (1), fluid ressure equalizes in both chambers (3 and 9). 'he tension of spring (7) closes piston (1).

Directional Control Valves

As previously mentioned, several different erms are used when referring to directional control valves. For example, in aircraft fluid power systems, directional control valves are commonly referred to as selector valves. However, the directional control valves in the systems of support equipment are usually referred to as control valves. Regardless of the term used, directional control valves direct the flow of fluid in a fluid power system.

Directional control valves may be classified according to the type of valving element. The ball, cone, poppet, rotary spool, and sliding spool are used as the valving elements. The ball, cone, or poppet is usually used as the valving element in check valves. In other types of directional control valves, the poppet, rotary spool, or sliding spool is used. The sliding spool directional control valve is most commonly used in the fluid power systems of ground support equipment.

The check valve, described previously, permits flow in one direction and prevents flow in

the other direction. For this reason, check valves are usually classified as one-way directional control valves. The other types of directional control valves are the two-way, the three-way, and the four-way valves.

The four-way control valve is the most widely used in ground support equipment. The typical four-way valve has four ports—a pressure port, a return port, and two working ports. The pressure port is connected to the main pressure line, and the return port is connected to the reservoir. The two working lines are connected to the actuating unit and serve alternately as pressure and return lines.

NOTE: In some subsystems, only one working line is required from the control valve to the actuator. Three-way valves are used in these systems. A three-way valve contains three ports—a pressure port, a return port, and one working port. Three-way valves operate similar to the four-way valve.

There are two main types of four-way control valves—the closed-center and the open-center. (Closed- and open-center hydraulic systems are described in chapter 14.) Figure 13-16 shows the operation of a closed-center control valve. View (A) shows the valve in the neutral position. In this position, there is no flow through the valve, as the two working ports (C1 and C2) are blocked off from the pressure and return ports.

View (B) shows the valve with the spool moved to the left of neutral position. In this position, one working port (C1) is open to pressure and the other working port (C2) is open to return. This allows the actuator to move in one direction.

When the actuator is moved in the opposite direction, the spool is moved to the right of neutral position, as shown in view (C) of figure 13-16. In this position, working port (C2) is open to pressure and working port (C1) is open to return.

Figure 13-17 illustrates the operation of a representative open-center control valve. When this type of valve is in the neutral position, as shown in view (A), fluid flows into the valve through the pressure port (P), through the hollow spool, and to return.

In view (B) the spool is moved to the right of the neutral position. In this position, one working line (C1) is open to pressure, and the other working line (C2) is open, through the hollow spool, to return. View (C) shows the flow of fluid with the spool moved to the left of neutral.

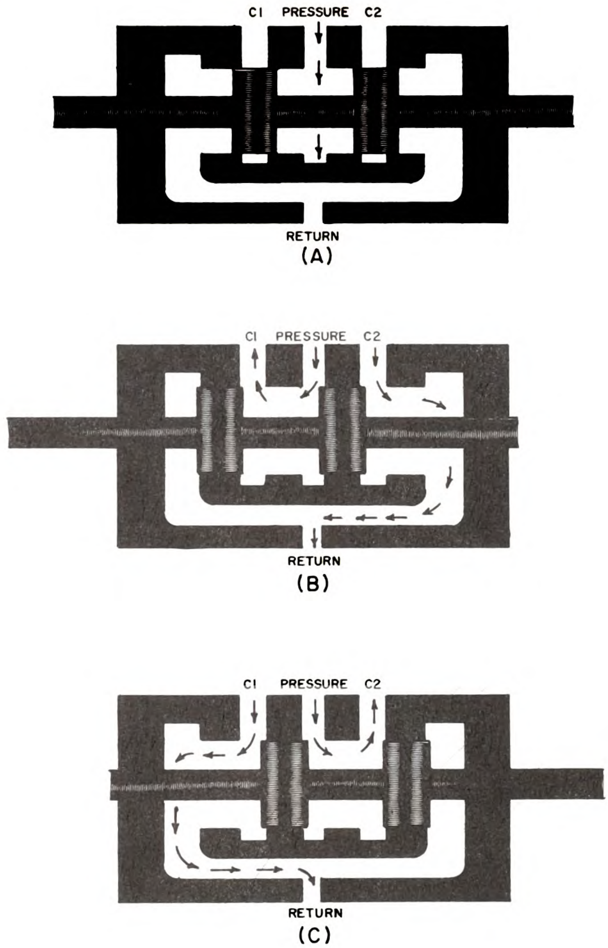


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Figure 13-16.—Closed-center directional control valve.

These control valves may be designed as individual units. However, in some systems, such as the hydraulic systems of weapons loaders and some forklifts, two, three, or four control valves are combined into one control unit.

Most directional control valves used in support equipment are operated manually, either directly or through mechanical linkage. In some systems, these valves are operated electrically. This is accomplished through the use of one or more solenoids.

A solenoid may be defined as a hollow tubular shaped electric coil, made up of many turns of fine insulated wire, and possessing the same properties as an electromagnet. The hollow coil imparts linear motion to a movable core

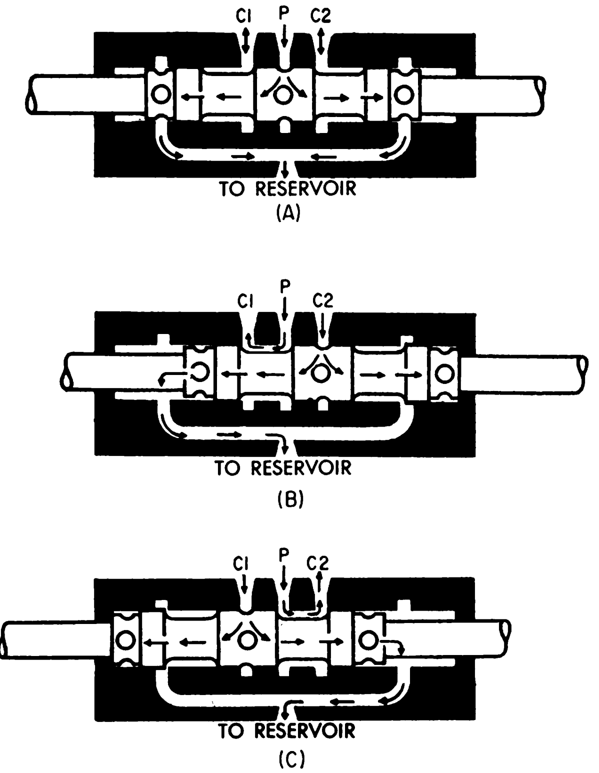

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Figure 13-17.—Open-center directional control valve.

or plunger) placed within the hollow coil of the olenoid.

To electrically operate the four-way valves hown in figures 13-16 and 13-17, a solenoid is onnected to each end of the valve. When the ollow coil of one solenoid is energized, the lunger of the solenoid moves and positions the liding spool accordingly. By energizing the olenoid on the opposite end, the sliding spool noves in the opposite direction. Springs are sually provided to move, and hold, the sliding pool to the neutral position when neither sole-oid is energized. The solenoids are electri-ally connected to switches which may be secured n a convenient location for the operator. Sole-oids are also used to operate two- and three-ay valves.

Maintenance

Due to the very close fit required at valve eats and around spools and sleeves, the most common cause of valve failure or malfunction is the presence of dirt or foreign matter. Particles of foreign matter can lodge in the valve seat, causing internal leakage. In addition, foreign particles will scratch lapped surfaces and damage seals. Some valves are provided with protective boots around the ends of the spool. These boots should be inspected frequently and replaced if necessary.

Proper linkage adjustment of control valves is necessary because linkage that is too long or too short will prevent the spool from moving the required distance in the valve.

It is important to check the applicable Instructions Manual before attempting to test or adjust valves. For example, a slight amount of internal leakage is permitted in some valves, and this should not be mistaken for faulty operation. In addition, a relief valve may be adjusted to relieve at 1,250 psi in one system, while in another system the correct relieving pressure may be 1,750 psi.

ACCUMULATORS

The purpose of the accumulator in a hydraulic system is to store a volume of fluid under pressure. There are several reasons why it is advantageous to store a volume of fluid under pressure. Some of these are as follows:

1. An accumulator acts as a cushion against pressure surges that may be caused by the pulsating fluid delivery from the pump or from system operations.

2. The accumulator supplements the pump's output, when the pump is under peak load, by storing energy in the form of fluid under pressure.

3. The energy stored in the accumulator may be used to actuate a unit in the event of normal hydraulic system failure. For example, sufficient energy can be stored in the accumulator for several applications of the brakes of a self-powered vehicle.

There are several different types of accumulators; however, the cylindrical type is most commonly found in ground support equipment. This type of accumulator is used in the hydraulic systems of weapons loaders. A cylindrical accumulator is illustrated in figure 13-18.

A cylindrical accumulator consists of a cylinder and piston assembly. Attached to both ends of the cylinder are end caps. The internal piston separates the fluid and air/nitrogen chambers. Both the end caps and piston are

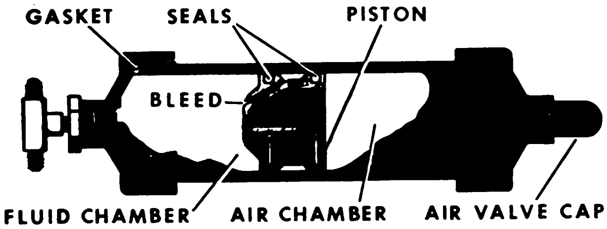

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Figure 13-18.—Cylindrical accumulator.

sealed, using gaskets and packings to prevent external leakage around the end caps and internal leakage between the chambers. In one end cap, a hydraulic fitting is used to attach the fluid chamber to the hydraulic system. In the other end, an air filler valve is installed. This valve (when open) allows an air/nitrogen source to be connected to and enter the accumulator; moreover, when the valve is closed, it traps the air/nitrogen within the accumulator.

In operation, the compressed-air chamber is charged to a predetermined pressure which is somewhat less than the system operating pressure. This initial charge is referred to as the accumulator PRELOAD.

As an example of accumulator operation, assume that the cylindrical accumulator in figure 13-18 is designed for a preload of 700 psi in a 1,500 psi system.

When the initial charge of 700 psi is introduced into the unit, hydraulic system pressure is zero. As air pressure is applied through the air pressure port, it moves the piston toward the opposite end until it bottoms. If the air behind the piston has a pressure of 700 psi, the pressure in the hydraulic system must increase to a pressure greater than 700 psi before the hydraulic fluid can actuate the piston. Thus, at 701 psi the piston will start to move within the cylinder, compressing the air as it moves. At 900 psi it will have backed up several inches. At 1,500 psi the piston will have backed up to its normal operating position, compressing the air until it occupies a space less than one-half the length of the cylinder.

When actuation of hydraulic units lowers system pressure, it is evident that the compressed air will expand against the piston, forcing fluid from the accumulator, thus supplying an instantaneous supply of fluid to the hydraulic system.

Maintenance

Accumulators should be visually examined for indications of external hydraulic fluid leaks. They should then be examined for external air leaks by brushing the exterior with soapy water, which will form bubbles where the air leaks occur.

The air valve assembly should be loosened to examine the accumulator for internal leaks. If hydraulic fluid comes out of the air valve, the accumulator should be removed and replaced. Before disassembly of an accumulator, insure that the air preload has been completely exhausted. This may be accomplished by loosening the swivel nut on the air filler valve until all air is out, then remove the valve.

The procedures for preloading an accumulator are described in chapter 14.

ACTUATORS

An actuator may be defined as a device which transforms fluid pressure into mechanical force to move some mechanism. One type of actuator is the motor, which converts fluid under pressure into rotary motion. This type actuator is used in some types of support equipment; for example, two hydraulic pump and motor combinations serve as the transmissions on spotting dollies.

The design and operation of motor are very similar to the power pumps described previously. In fact, several types of hydraulic pumps may be used as motors with little or no modifications. In an axial piston motor, fluid under pressure is directed through one of the ports. This flow of fluid forces the pistons to move in the cylinder block, rotating the block and the drive shaft. Detailed descriptions and illustrations of different types of motors, including pump and motor transmissions, are contained in Fluid Power, NavPers 16193 (Series).

The most common actuator used in support equipment is the actuating cylinder. The function of this actuator is to convert fluid under pressure into linear or reciprocating mechanical motion. There are two main types of actuating cylinders—the single-action type and the double-action type.

NOTE: The terms piston and ram are both used when referring to the movable element of an actuating cylinder. The term ram is normally associated with those movable elements which have no piston rod and which are used

primarily for push functions. Movable elements which are attached to piston rods and are used for both push and pull functions are called pistons.

Single-Action Actuating Cylinders

Single-action actuating cylinders are designed to allow piston (ram) travel in one direction through the use of fluid under pressure. Ram travel in the opposite direction is provided by some other force, usually gravity (weight). For example, in the actuating cylinders of hydraulic jacks, workstands, and some models of forklifts, hydraulic fluid provides the force to raise the rams, and the weight of the load lowers the ram.

Two examples of single-action actuating cylinders are illustrated in figure 13-19. View (A) shows a single ram cylinder. This type of cylinder is used in hydraulically operated workstands and as the lift cylinder on some models of forklifts. Fluid is forced into the bottom of the cylinder to extend the ram. To retract the ram, fluid is allowed to flow out of the cylinder to the reservoir. The weight of the ram and any load that it might carry forces the ram to retract into the cylinder.

A telescoping ram cylinder assembly is shown in figure 13-19 (B). This type of actuating cylinder is used in most hydraulic jacks. This cylinder operates similar to the single ram cylinder. Fluid is forced into the bottom of the cylinder to extend the rams. Since the fluid pressure acts on the entire cross-sectional area of ram (1), this ram will extend first. When the lip of ram (1) strikes the stop of ram (2), ram (2) will extend. This action continues until the desired extension is reached or until the lip of ram (3) strikes the stop of the cylinder.

A typical double-action actuating cylinder is illustrated in figure 13-20. This type of cylinder operates under the influence of fluid flow in either direction. The cylinder contains one piston and piston rod assembly. The two fluid ports one near each end of the cylinder, alternate

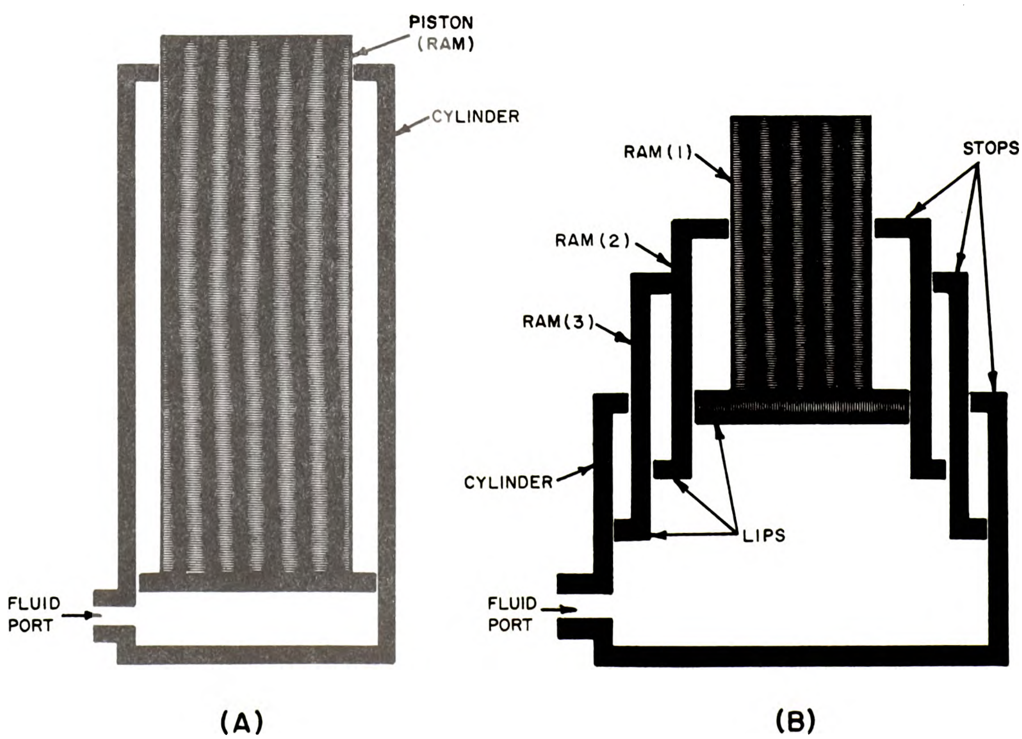

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Figure 13-19.—Single-action actuating cylinders.

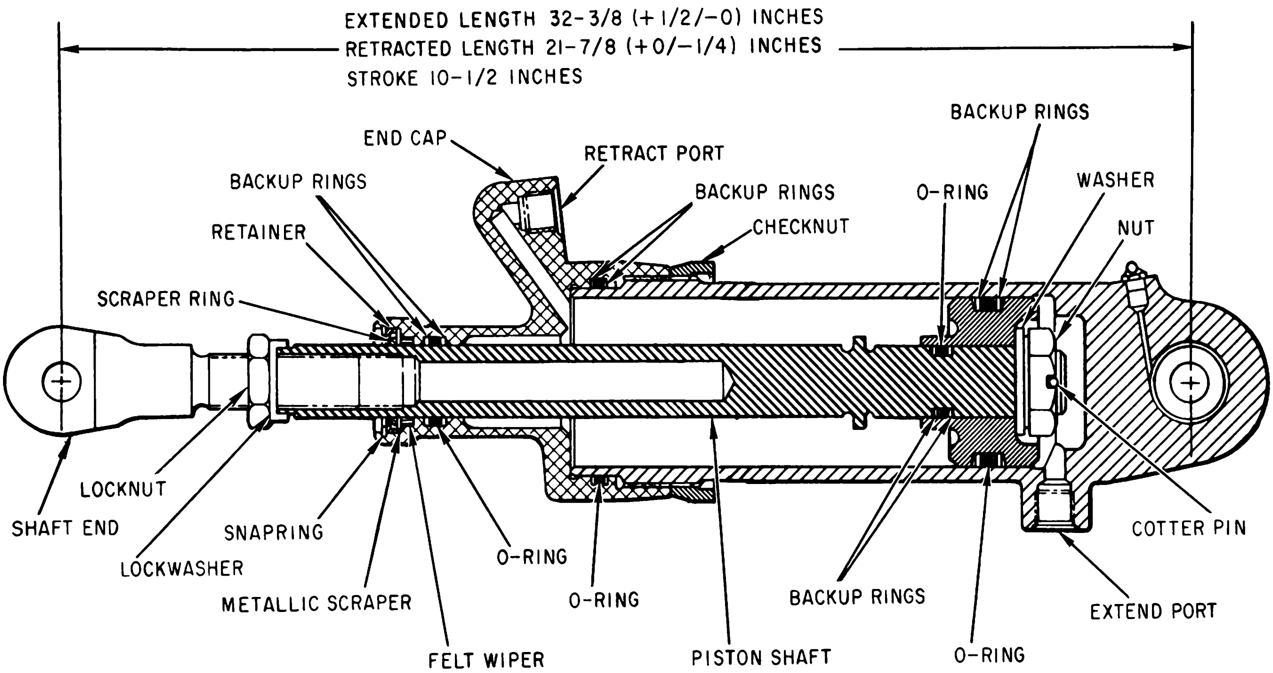

Figure 13-20.—Typical cross-sectional view of a double-acting actuating cylinder.

as inlet and outlet ports, depending on the direction of flow from the directional control valve.

This is an unbalanced actuating cylinder; that is, there is a difference in the effective working areas on the two sides of the piston. Fluid pressure acts on the entire area of one side of the piston (the blank side). However, due to the area of the piston rod on the other side of the piston (the rod side), fluid pressure acts on a smaller area. For this reason, this type actuating cylinder is normally installed in such a manner that the blank side of the piston carries the greatest load; that is, the cylinder carries the greater load during the extension stroke.

Maintenance of Actuating Cylinders

During preventive maintenance inspections, the ASH inspects actuating cylinders for leakage and binding. The exposed portion of the piston shaft is cleaned, using a drycleaning solvent, and then wiped with a clean cloth moistened with hydraulic fluid. All mounting fittings are lubricated using a specified grease.

NOTE: All lubrication fittings and lubrication areas must be cleaned prior to lubrication, and all excess lubricants must be removed at its completion.

Leakage is the most common trouble encountered with actuating cylinders. External leaks are the greatest problem; therefore, all actuating cylinders should be inspected carefully and regularly for such signs.

Leakage around end caps may sometimes be stopped by tightening the caps; however, if tightening does not stop the leak, the end cap seals must be replaced.

The procedure for disassembling and reassembling a typical hydraulic actuating cylinder for replacement of parts is outlined in the following paragraphs. In actual practice, the ASH must refer to the applicable Instructions Manual for specific maintenance instructions and applicable safety instructions. An example of disassembling as well as assembling instructions for a typical actuating cylinder follows:

1. Secure the actuating cylinder in a holding device, such as a wooden block formed to fit the outer circumference of the cylinder body.
2. Remove all fluid fittings.
3. Loosen the shaft end locknut and remove the shaft end and lockwasher. (See fig. 13-20.)

. Cut the end cap checknut lockwire and rew both the checknut and end cap from the ıder body. (Some checknuts are secured ıe lock position with setscrews vice lock-s.)

. Using needle-nose snapring pliers, re-ɘ the end cap snapring and then remove the iner, scraper, washer, felt wiper, backup s, and O-rings as previously described in ter 5.

. Pull the piston shaft assembly from the ıder body.

. Remove the cotter pin from the piston t and unscrew the nut, then remove the ıer and piston from the piston shaft.

. Exercise care while removing the O-ring backup rings from both the piston and the ve in the piston shaft.

'rior to assembling, all cylinder parts ld be cleaned with an approved drycleaning ent and dried with filtered compressed air. ng inspection of the parts, handle each part fully to avoid nicks, scratches, or dents to piston, piston cylinder, and end caps. Minor tches are removed by using crocus cloth. or nicks or burrs are removed with a hon-stone. Examine all threaded parts for con-n and cleanliness. Inspect O-ring and up ring seating surfaces for rough edges could damage the rings.

'rior to assembly, all parts should be laid on a clean surface in the proper assembling r, and the following general steps should be wed during assembly:

. Install O-ring and backup rings in the ve near the end of the piston shaft as illus-ed in figure 5-32 in chapter 5.

. Assemble the piston to the piston shaft hat the nut will fit in the recess of the pis- Secure the nut in place, using a new cotter

. Install a new O-ring and two backup rings ıe groove of the piston.

. Carefully insert the piston and shaft into cylinder body, insuring that the O-ring in piston groove remains seated.

. Install the O-rings and backup rings within grooves provided in the end cap.

. Screw the large checknut on the threaded ion of the cylinder body a sufficient amount llow the end cap to be screwed on until it oms out. Back off the end cap, no more than full turn, until the fluid ports are aligned as cated in the Instructions Manual.

7. Install the felt wiper, plain washer, scraper ring, and retainer in the end cap. Then secure these items with a snapring. Insure that the snapring seats properly in the groove.

8. Tighten the end cap checknut and safety into position, using the prescribed safety device.

9. Install the shaft end, lockwasher, and checknut. Adjust the shaft end to obtain approximately the stroke dimensions as indicated in the applicable Instructions Manual and tighten the checknut. An example of the dimensions of an actuator is usually given in both the extended and retracted positions as shown in figure 13-20.

Testing of actuating cylinders is required after disassembling and assembling procedures. Although testing procedures are similar from one actuating cylinder to another, pressures as well as specific procedures may differ between manufacturers. Units tested must meet all of the requirements of the test procedures specified in the applicable Instructions Manual prior to their return to service. The following are steps used while testing a typical actuating cylinder; however, the ASH must refer to the specific Instructions Manual for a specific test procedure.

1. With the extend port open, apply 2,500 psi pressure to the retract port; piston will bottom.

2. Maintain this pressure for a period of 2 minutes. During this time there should not be any internal leakage or damage to the cylinder.

3. Apply 2,000 psi pressure to the extend port.

4. Maintain this pressure for a period of 2 minutes. During this time there must be no internal or external leakage or damage to the cylinder.

5. With 1,500 psi pressure, cycle the cylinder 25 times. Leakage of one drop is 25 cycles is permitted around the piston shaft. No other leakage is permitted.

6. To adjust the stroke, apply 1,500 psi pressure to the retract port and bottom the cylinder. At this time adjust the shaft end to its proper length. For most cylinders, extended and retracted dimensions are measured from the center of the mounting fittings, as shown in figure 13-20.

7. Apply 1,500 psi pressure to the extend port, which will bottom the piston shaft in the extended position. The length should be as specified in the applicable Instructions Manual.

8. Remove the cylinder from the hydraulic test stand. If the cylinder is not to be put into use immediately, it must be flushed with the approved preservation fluid, drained to the drip point, and both ports plugged.

If the cylinder is to be installed directly on an item of equipment, the cylinder piston is positioned in its respective installation position and filled with filtered fluid. This helps eliminate the entry of large quantities of air into the system. The small amount of air that does enter the system, due to open lines, is bled from the system by actuating the affected system five or more times.

GAGES AND METERS

Pressure gages installed in hydraulic and pneumatic systems are used to indicate existing pressures, and are calibrated in pounds per square inch. Flowmeters are used in hydraulic test stands and component test benches to indicate the rate of flow in gallons per minute. For example, the flowmeter is required when testing the output of pumps.

The most common type of flowmeter is the rotameter which is described and illustrated in Fluid Power, NavPers 16193-B. The Bourdon tube pressure gage is commonly used in the fluid power systems of support equipment. An example of this type gage is described in the following paragraphs.

Most gages used in the fluid power systems of support equipment are the direct reading type; that is, the gage is connected directly into the unit or lines leading to the unit and becomes part of the container or system. The gage is able to sample existing pressures at these points.

The main part of the gage is the Bourdon tube. The Bourdon tube is a curved metal tube which is oval in cross-sectional shape, as illustrated in figure 13-21. One end of the Bourdon tube is closed, while the other has a fitting for connecting it to a pressure source. The fitting end is fastened to the gage frame, while the other end is free to move so it can operate the mechanical linkage.

Assume that fluid pressure enters the Bourdon tube. Since fluid pressure will be transmitted equally in all directions and the area on the outside radius of the tube is greater than that of its inside, the force will also be greater on the outside radius which tends to straighten out the tube. As the movable end of

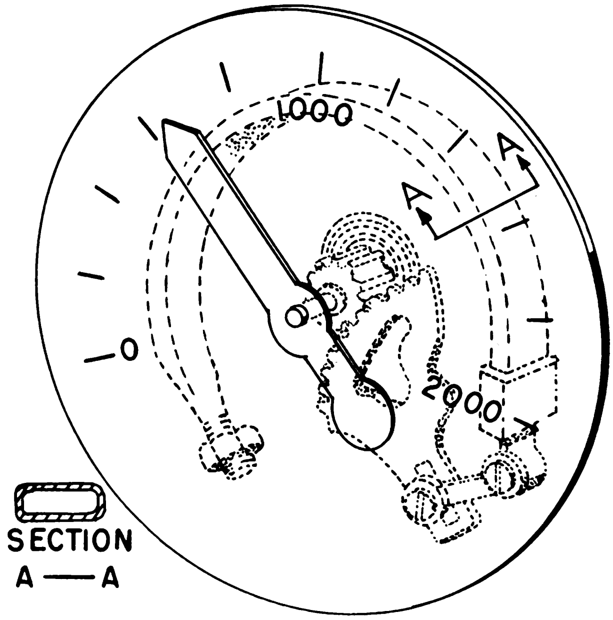

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Figure 13-21.—Bourdon tube.

the tube tries to turn outward, it turns the pivot segment gear. This gear meshes with a smaller rotary gear to which a pointer is attached, and its movement causes a reading on the pressure gage. The gage dial is calibrated so the needle points to a number which corresponds to the exact pressure which is applied. When the pressure is removed, the Bourdon tube acts as a spring and returns to its normal position.

Pressure gages are designed to indicate several different ranges of pressures. In support equipment, these gages range from 0 to 100 psi, 0 to 250 psi, 0 to 1,000 psi, etc., up to 0 to 6,000 psi and higher. An example of a 0 to 2,000 psi hydraulic pressure gage is illustrated in figure 13-22.

Pressure Gage Snubbers

A pressure gage snubber is a hydraulic component located upstream of pressure gages in some systems. Its purpose is to dampen out system pressure surges causing possible damage to gages. Without the use of a snubber, pressure oscillations and other sudden pressure changes could affect the delicate internal mechanism of the gages.

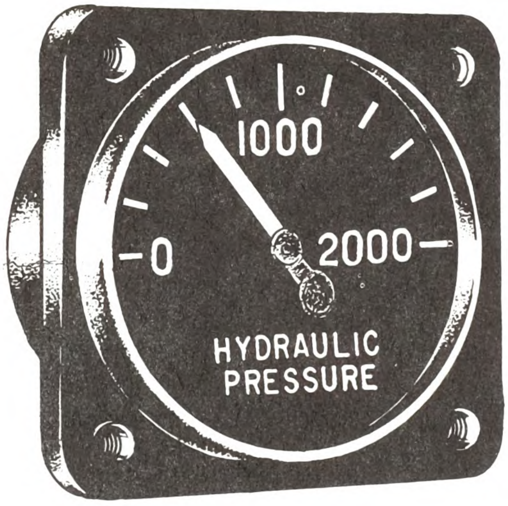

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Figure 13-22.—Hydraulic pressure gage (0 to 2,000 psi range).

The basic components of a snubber are the housing, fitting assembly with a fixed orifice diameter, and the pin and plunger assembly, as illustrated in figure 13-23. The snubbing action is obtained by metering fluid through the snubber. The fitting assembly orifice restricts the amount of fluid that flows to the gage, thereby snubbing the force of a pressure surge. The pin is pushed and pulled through the orifice of the fitting assembly by the plunger, keeping it clear and at uniform size.

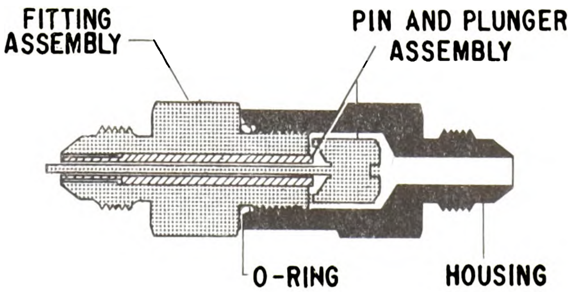

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Figure 13-23.—Pressure gage snubber.

AIR COMPRESSORS

As previously mentioned, compressed air is commonly used in pneumatic systems of ground support equipment. Nitrogen is another compressed gas used in pneumatic systems, especially in aircraft. Many of the uses of pneumatics are covered elsewhere in this manual. The pneumatic rivet gun is covered in chapter 5, the dry honing machine is described in chapter 10, pneumatic brake systems are discussed in chapter 15, and several different types of paint spraying equipment are covered in chapter 17.

The source of power for pneumatic systems is the air compressor. Since the receiver, valves, and other components are usually considered as part of the compressor, they are also included in this discussion. The fundamental principles of the air compressor and its components are covered in Fluid Power, NavPers 16193-B, and should be studied in conjunction with the following discussion.

Several different sizes of air compressors are required in the operation and maintenance of support equipment. A small compressor, driven by the engine, is utilized on vehicles equipped with pneumatic brake systems. Compressed air required for the operation of tools and maintenance equipment is supplied by either a portable air compressor or a large stationary compressor. These compressors are driven by an electric motor, a gasoline engine, or a diesel engine. A schematic of a gasoline-engine-driven air compressor is illustrated in figure 13-24. Although the stages of compression and the quantity and types of components may vary in different compressors, the principles of operation of all compressors are similar to the one described here.

Compressor

The compressor (3) is of the air-cooled type with five single stage cylinders arranged radially about the crankcase. Lubrication of the moving parts is provided by a gear pump, which is chain driven by a sprocket mounted on the crankshaft. The crankshaft is supported at each end with ball bearings. The connecting rods are of the solid type with roller bearings at the piston pin ends and ball bearings at the crankshaft ends. A cast aluminum fan, mounted on the end of the compressor, provides a supply of cooling air through the inter-aftercooler.

The inter-aftercooler is of the finned-core type with separate inlet and outlet ports for each stage of compression. Ports are also provided for connection of the compressor control system tubing and interstage safety valves. Manually operated shutters are provided for controlling the flow of cooling air through the inter-aftercooler.

Compressor Control System

The compressor control system consists of the switches, valves, and interconnecting tubing shown in figure 13-24. The purpose of this system is to control the compression of air by the compressor and to remove accumulated (moisture) from the condensate receivers and air receivers.

The pilot valve (15, fig. 13-24) is an air valve installed in the control line between the air receivers (10 and 11) and the blowdown valve (17). The purpose of the pilot valve is to control the flow of air from the receivers to the blowdown valve. The pilot valve can be manually adjusted so the air from the receivers can flow through it at all times, or so that no air can flow through it until the air in the receiver reaches a pressure of 5,000 psi. When the pressure in the receiver reaches 5,000 psi, the valve opens automatically to permit air to flow through it. When adjusted for automatic opening, the valve also closes automatically when the receiver pressure drops to 4,500 psi. The pressures at which the valve automatically opens and closes are known as the "unload" and "load" pressures, respectively.

The blowdown control valve (16) is a solenoid-actuated three-way valve installed in the control line from the first stage cylinder to the blowdown valve. The purpose of this valve is to control the flow of air to the low-pressure chamber of the blowdown valve. When the solenoid is energized, the valve is open so that air from the first stage cylinder may flow through it. When the solenoid is deenergized, the valve is vented to the atmosphere. The solenoid is operated manually by manipulation of the unloader switch (49).

The blowdown valve (17) is a pressure-actuated air valve containing four separate air passages. This provides a means of venting the first four compressor stages to the atmosphere. All four air passages are open or closed in proper sequence due to air pressure admitted to the valve body through the pilot valve and/or the blowdown control valve. In addition to preventing the compression of air by the compressor, opening the air passages in the blowdown valve causes the moisture accumulated in the interstage condensate chambers to be blown out to the atmosphere.

The automatic drain valve (14) is a solenoid-actuated three-way valve installed in the outlet side of the condensate receiver (12) for the air receivers. The purpose of this valve is to permit draining condensate from the air receivers without loss of pressure in the receivers. The solenoid is electrically connected to and controlled by the timer.

The timer (5) is an electric-motor-operated switch. Operation of the switch is controlled by a cam mounted on the end of the motor shaft, which bears against a roller (follower) on the end of the switch lever arm. The timer cycle is approximately 7 minutes, during which the switch is open for approximately 6 1/2 minutes and closed for approximately 1/2 minute. Input power to the timer motor is through the compressor oil pressure switch (4). Consequently, when the contacts in the compressor oil pressure switch are open, the timer is in operation and the control circuit to the automatic drain valve is open.

The oil pressure switch (4) is a pressure-actuated switch installed in the line to the oil pressure gage. This switch is of the normally open type; that is, the switch contacts are open whenever the compressor oil pressure is less than 3 psi. This prevents loading of the compressor whenever compressor lubrication is not adequate.

The unloader switch (49) is a toggle type switch which is electrically connected between the oil pressure switch and the blowdown control valve. The purpose of this switch is to interrupt the circuit to the solenoid of the blowdown control valve, which causes the blowdown to open (or, if already open, to remain open) to prevent compression of air by the air compressor.

There are two receivers (10 and 11) in this compressor system. The receivers are spherical metal containers and are interconnected. One receiver is provided with a pressure relief valve (6), which is adjusted to relieve pressure in excess of 5,500 psi. The other receiver is provided with a rupture disc (8) and a pressure gage (9). In case all other safety features fail, the disc is set to rupture and relieve pressure from the receivers. The disc is preset to

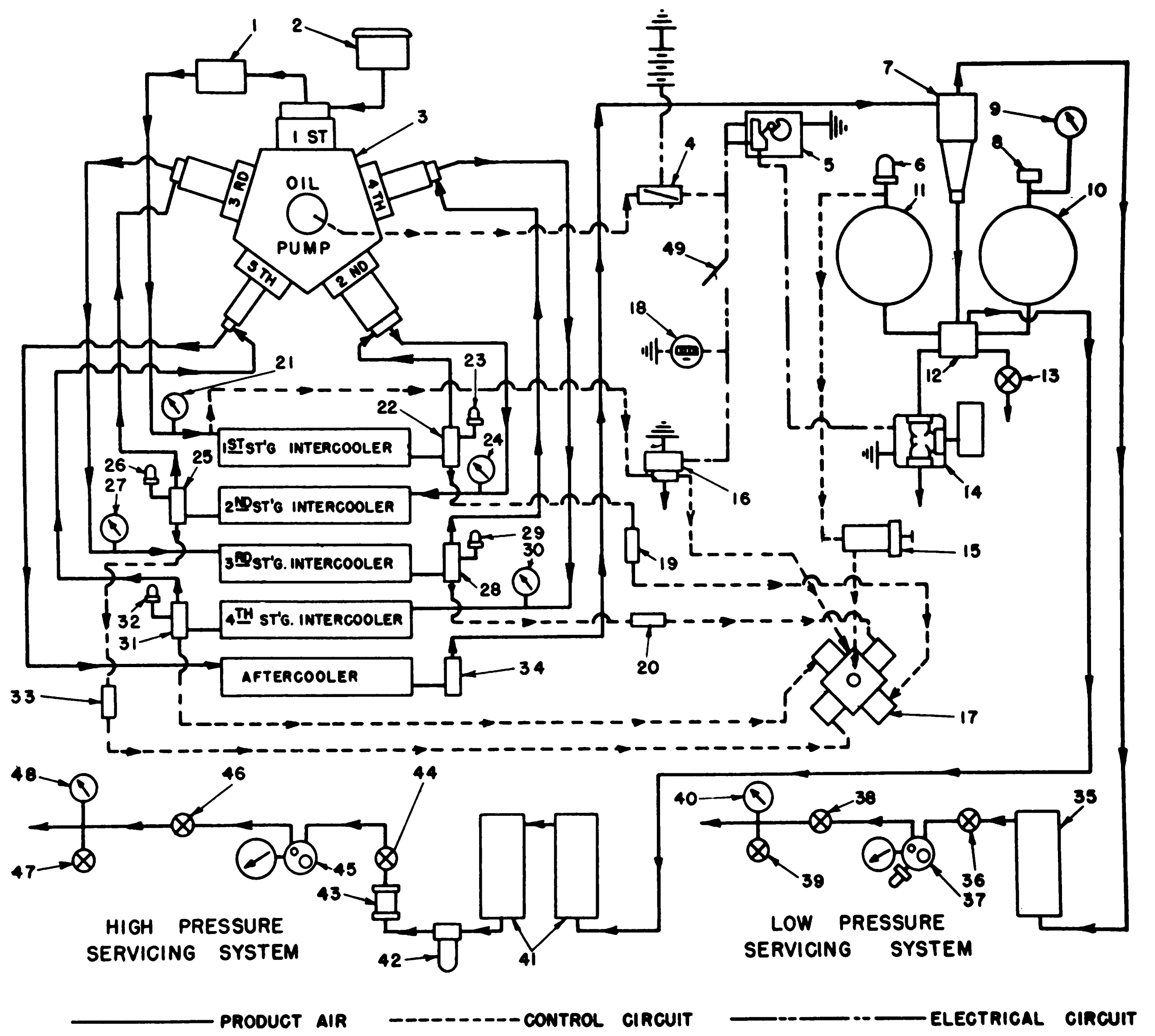

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Figure 13-24.—Schematic diagram of an air compressor.

rupture at a pressure somewhere between 5,500 psi and the burst pressure of the receivers.

The air receiver pressure gage (9) indicates the pressure in the aftercoolers and the air receivers. The pressure in the air receivers must never be permitted to exceed the maximum operating pressure of 5,000 psi. Should the gage indicate pressure in excess of 5,000 psi, the compressor must be immediately unloaded and the cause of the excessive pressure determined and corrected.

Each of the four intercooler stages are provided with a pressure gage (21, 24, 27, and 30). The normal operating pressures which should be indicated on these gages are shown in table 13-2.

The hourmeter (18) indicates the number of hours of compressor "loaded" operation. The

Nomenclature for figure 13-24

1. Surge chamber.
2. Air filter.
3. Compressor.
4. Oil pressure switch.
5. Timer.
6. Pressure relief valve.
7. Moisture separator.
8. Rupture disc.
9. Air receiver pressure gage.
10. Air receiver.
11. Air receiver.
12. Condensate receiver.
13. Receiver drain valve.
14. Automatic drain valve.
15. Pilot valve.
16. Blowdown control valve.
17. Blowdown valve.
18. Hourmeter.
19. First stage condensate chamber.
20. Third stage condensate chamber.
21. First stage pressure gage.
22. First stage moisture separator.
23. First stage pressure relief valve.
24. Second stage pressure gage.
25. Second stage moisture separator.
26. Second stage pressure relief valve.
27. Third stage pressure gage.
28. Third stage moisture separator.
29. Third stage pressure relief valve.
30. Fourth stage pressure gage.
31. Fourth stage moisture separator.
32. Fourth stage pressure relief valve.
33. Second stage condensate chamber.
34. Aftercooler moisture separator.
35. Dehydrator.
36. Service valve.
37. Pressure regulator.
38. Shutoff valve.
39. Relief valve.
40. Service line pressure gage.
41. Dehydrator.
42. High-pressure air filter.
43. Priority valve.
44. Service valve.
45. Pressure regulator.
46. Shutoff valve.
47. Relief valve.
48. Service line pressure gage.
49. Unloader switch.

Table 13-2.—Normal intercooler air pressures.

Intercooler stage	Minimum gage pressure	Maximum gage pressure
First	50 psi	56 psi
Second	210 psi	230 psi
Third	670 psi	770 psi
Fourth	1,725 psi	1,925 psi

purpose of this record is to assist in determining the periods for performing periodic maintenance and servicing.

Low-Pressure Servicing System

The low-pressure servicing system consists of a dehydrator (35), pressure regulator (37), service line pressure gage (40), three valves (36, 38, and 39), and interconnecting tubing. This system is used as a source of compressed air for pressure up to 1,000 psi. Descriptions of the system components are contained in the following paragraphs.

The dehydrator (35) consists of a cylinder with an oxygen purifier cartridge. The cartridge, sometimes referred to as a chemical drier, absorbs moisture as the air passes through the cylinder. The cylinder is equipped with spring-loaded perforators at both top and bottom. The perforators open the ends of the cartridge at the time of installation. The effective life of the cartridge is related to the ambient temperature in which it operates. The type cartridge and dehydrator servicing schedule are contained in the applicable Instructions Manual.

The pressure regulator (37) is essentially an automatic metering valve in which the volume of air that is permitted to flow through a fixed orifice in the valve body determines the outlet (regulated) pressure. This volume is controlled by a spring-loaded, tapered valve which is positioned with respect to the orifice (valve seat) by means of a pressure-sensitive diaphragm. This neoprene diaphragm responds to variations in balance between the pressure in two

ir chambers which are separated by the diahragm.

Initial pressure balance between the two hambers is established by manual adjustment f two valves in the regulator. The valves are djusted by turning two knobs on the front of ne regulator. One knob is marked "LOAD," nd the other knob is marked "BLEED." The LOAD" valve meters inlet pressure into the hamber to load the diaphragm and to establish ne desired outlet (regulated) pressure. The BLEED" valve discharges the load pressure rom the chamber to the atmosphere. The egulator is provided with a pressure gage to ndicate the outlet pressure and a pop safety alve which is adjusted to open at approximately ,150 psi.

There are three identical manually operated eedle valves (36, 38, and 39) installed on the utlet side of the dehydrator. These valves ermit isolating various components and secions of the low-pressure servicing system. 'he service valve (36) permits the compressor o be operated without pressurizing the pressure egulator. The shutoff valve (38) permits the djustment of the pressure regulator without ressurizing the servicing hose. The relief alve (39) permits relieving the pressure in the ervicing hose (after charging a pneumatic ystem) before disconnecting the servicing hose rom the equipment being charged.

ligh-Pressure Servicing System

The high-pressure servicing system consists f a dehydrator (41), air filter (42), priority alve (43), pressure regulator (45), service line ressure gage (48), three valves (44, 46, and 47), nd interconnecting tubing. This system is used s a source of compressed air for pressures rom 1,000 psi up to 5,000 psi. Descriptions of ne high-pressure servicing components are ontained in the following paragraphs.

The dehydrator (41) is similar to the deydrator in the low-pressure system except hat there are two cylinders in the high-pressure ystem.

The air filter (42) is a dry type unit which tilizes a replaceable paper filtering element. 'he purpose of this filter is to prevent foreign natter from entering the priority valve and endering it inoperative.

The priority valve (43) is an automatic air alve installed in the line between the air filter and the pressure regulator. It opens automatically when the pressure in the line from the air filter reaches approximately 2,800 psi. It closes automatically whenever the inlet pressure drops below 2,800 psi. The purpose of this valve is to assure maximum effectiveness of the dehydrator. The dehydrator absorbs more moisture from the air when the pressure is above 2,800 psi.

The pressure regulator (45) in the high-pressure system is identical to that in the low-pressure system except that it does not include a pop safety valve and the range of the pressure gage is greater.

The construction and purpose of the valves (44, 46, and 47) in the high-pressure system are identical to those used in the low-pressure system.

Principles of Operation

The operating principle of the compressor is that of multistage compression, in which the intake air is compressed to the desired discharge pressure in five distinct stages. In other words, only the first stage cylinder intake air is at atmospheric pressure. Intake air for the remaining cylinders is at the discharge pressure (and reduced volume) of the preceding stage.

The heat which results from compression is partially removed after each stage of compression by passing the air through the five separate sections of the inter-aftercooler. Individual moisture separators are provided on the "cold" side of each section of the inter-aftercooler to remove the condensation resulting from the lowering of the air temperature by the inter-aftercooler. The condensate thus removed drains into separate reservoirs, or condensate chambers, where it is temporarily stored for periodic removal through the blowdown valve.

Three methods of operation (one automatic and two manual) are provided for controlling the compression of air by the compressor. The automatic method is normally employed, but either manual method of unloading the compressor may be used when desired.

In the automatic method of control, the pilot valve handle is placed in the "load" position and the unloader switch lever is placed in the "load" position. This causes the blowdown valve to be actuated periodically in response to the air receiver pressure. The unit automatically

unloads at approximately 5,000 psi and loads at approximately 4,500 psi.

In one method of manual control, unloading the compressor is accomplished by moving the unloader switch level to the "unload" position. In the other method of manual control, unloading the compressor is accomplished by turning the pilot valve handle to the "unload" position. When the air receivers are at the maximum permissible pressure (5,400 psi) and unloading cannot be effected by use of the unloader switch (due to malfunctioning of the control systems components), this method should be used for emergency unloading.

Operating Procedures

Figure 13-25 shows the location of the compressor operating controls on the instrument panel. Each time the compressor is to be operated, the following steps must be performed:

1. Position the compressor adjacent to the equipment to be charged, and set the parking brakes.
2. Open the trailer housing doors. Leave the housing doors open to assure adequate ventilation for the engine and the compressor.
3. Close the valves (21, 22, and 24, fig. 13-25) in the low-pressure servicing system.
4. Close the valves (26, 28, and 29) in the high-pressure servicing system.
5. Make sure that the unloader switch lever (33) is in the "unload" position.
6. Make sure that the clutch lever (18) is in the engaged position.
7. Connect the desired servicing hose (20 or 30) to the pneumatic system to be charged.

The steps involved in the engine starting procedure are as follows:

CAUTION: Never start the engine or operate the compressor in an enclosed space without ventilating the engine exhaust gases to the outside atmosphere.

NOTE: Insure that the compressor clutch lever is in the disengaged position before starting the engine.

1. Pull the choke control (11) part way out. The amount of choking required depends upon both the engine temperature and the ambient temperature. If the engine is warm, or if the ambient temperature is very high, very little choking is necessary.
2. Push the ignition switch (3) all the way in to the "running" position.
3. Press the starter switch (4), and allow the starter to crank the engine until it starts.

NOTE: The starter should not be operated continuously for more than 30 seconds. If the engine does not start within 30 seconds, wait a few minutes before operating the starter again.

4. After the engine starts, observe the engine oil pressure gage (9) and ammeter (5). If the oil pressure gage does not indicate pressure within 30 seconds after the engine starts, pull the ignition switch to the "stop" position and determine the cause of failure. If the ammeter does not show a "charge" reading immediately after starting, determine the cause.
5. Allow the engine to operate at idling speed until it is at normal operating temperature. During this warmup period, gradually push the choke control all the way in against the instrument panel.

The procedure for starting the compressor is as follows:

NOTE: Insure that all manual control valves are closed and the unloader is in the unload position before engaging the compressor.

1. After the engine is warmed up so that it operates smoothly at idling speed, pull the engine speed regulator knob (12) part way out to increase the engine speed to a fast idle.
2. Move the clutch lever to the engaged position; the compressor should start operation.
3. Observe the compressor oil pressure gage (16). If the gage does not indicate pressure within 1 to 2 minutes after the compressor starts, disengage the clutch and determine the cause of malfunction.
4. Pull the engine speed regulator knob out as far as possible (for maximum governed engine speed), and lock the control in that position.
5. Place the unloader switch lever (33) in the "load" position.
6. Observe the intercooler stage pressure gages. All gages should indicate almost immediately, gradually increasing, but less than normal, pressure. Normal pressures should be indicated on each gage in turn, starting with the first stage gage. (See table 13-2.) If the pressure indicated for any stage is less than normal after the air receiver pressure gage (8) indicates pressure in excess of the normal maximum pressure for that stage, stop the compressor and determine the cause.

NOTE: At least once each hour during compressor operation, move the unloader switch to the "unload" position. This will cause the condensate chambers to be blown out to atmosphere

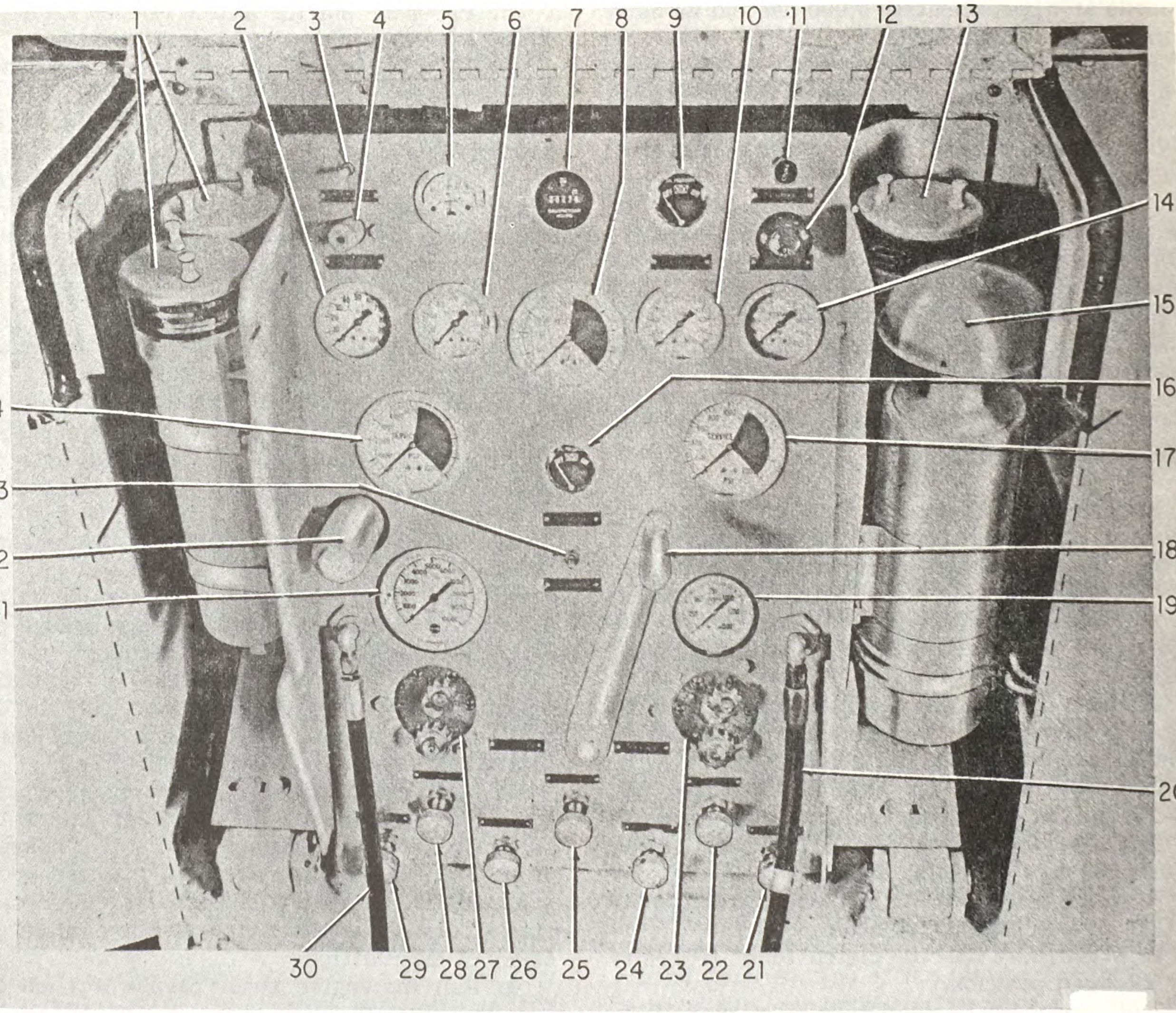

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Figure 13-25.—Air compressor control panel.

rough the blowdown valve. After all condensate blown out, return the unloader switch lever the "load" position.

The procedure for using the low-pressure rvicing system is as follows:

1. Close "load" valve of the low-pressure gulator (23).
2. Open "bleed" valve of the low-pressure gulator one-half turn.
3. Open the low-pressure servicing system lve (22).
4. Close the regulator bleed valve and open the load valve slowly until the desired output (regulated) pressure is indicated on the gage (19), then close finger tight. To reduce outlet pressure, open the bleed valve as necessary.
5. Open the low-pressure service shutoff valve (24).
6. Charge the equipment being serviced until the service line gage (17) shows a steady pressure reading. This indicates that the pressure in the servicing line and the system being charged is equalized.

Nomenclature for figure 13-25.

1. High-pressure dehydrator cylinders.
2. First stage pressure gage.
3. Ignition switch.
4. Starter switch.
5. Ammeter.
6. Second stage pressure gage.
7. Hourmeter.
8. Air receiver pressure gage.
9. Engine oil pressure gage.
10. Third stage pressure gage.
11. Choke control.
12. Engine speed regulator.
13. Low-pressure dehydrator cylinder.
14. Fourth stage pressure gage.
15. Engine air cleaner.
16. Compressor oil pressure gage.
17. Low-pressure service line pressure gage.
18. Clutch lever.
19. Low-pressure regulator pressure gage.
20. Low-pressure service hose.
21. Relief valve.
22. Service valve.
23. Low-pressure regulator.
24. Shutoff valve.
25. Air receiver drain valve.
26. Relief valve.
27. High-pressure regulator.
28. Service valve.
29. Shutoff valve.
30. High-pressure service hose.
31. High-pressure regulator pressure gage.
32. High-pressure air filter.
33. Unloader switch.
34. High-pressure service line gage.

7. Close the low-pressure service shutoff valve.

8. Open the low-pressure servicing line relief valve (21).

9. After the needle of the service line gage drops to zero, disconnect the servicing hose (20) from the system that has been charged.

10. Move the unloader switch lever to the "unload" position, and note that the compressor blows down. If it does not, turn the pilot valve handle to the unload position. After the compressor unloads, determine the cause of the unloader switch malfunction and perform the necessary corrective maintenance procedures.

The operation of the high-pressure servicing system is the same as that described for the low-pressure servicing system, except that the high-pressure valves and gages are used.

After the equipment is charged, the compressor and engine should be shut down by adhering to the following procedure:

1. Place the unloader switch lever (33) in the "unload" position.

2. Open the air receiver drain valve (25).

3. Observe the intercooler stage and air receiver pressure gages, and note that all gages return to zero.

4. After all pressure in the compressor is relieved, release the speed regulator control lock, and push the regulator knob (12) in until the engine speed drops to a fast idle.

5. Move the clutch lever (18) to the disengaged position.

6. Close the air receiver drain valve.

7. After shutting down the compressor, push the speed regulator in as far as possible, and allow the engine to idle for 3 to 5 minutes.

8. Pull the ignition switch (3) all the way out ("stop" position); the engine should stop.

9. Coil the servicing hoses (20 and 30) around the brackets provided on the sides of the instrument panel.

10. Close and latch the trailer housing doors.

Maintenance

The applicable Instructions Manual and Maintenance Requirements Cards for the specific air compressor must be consulted for the inspection interval and procedures, and for correct repair procedures.

Like the inspections of all types of aviation support equipment, the inspection of air compressors consists of examining, checking, and testing the components, lines, and fittings to insure that the operation of the compressor will not be interrupted due to premature failure of parts and assemblies. In addition, these procedures serve to prevent extensive damage which might otherwise occur due to improper adjustment, insufficient lubrication, or vibration of parts.

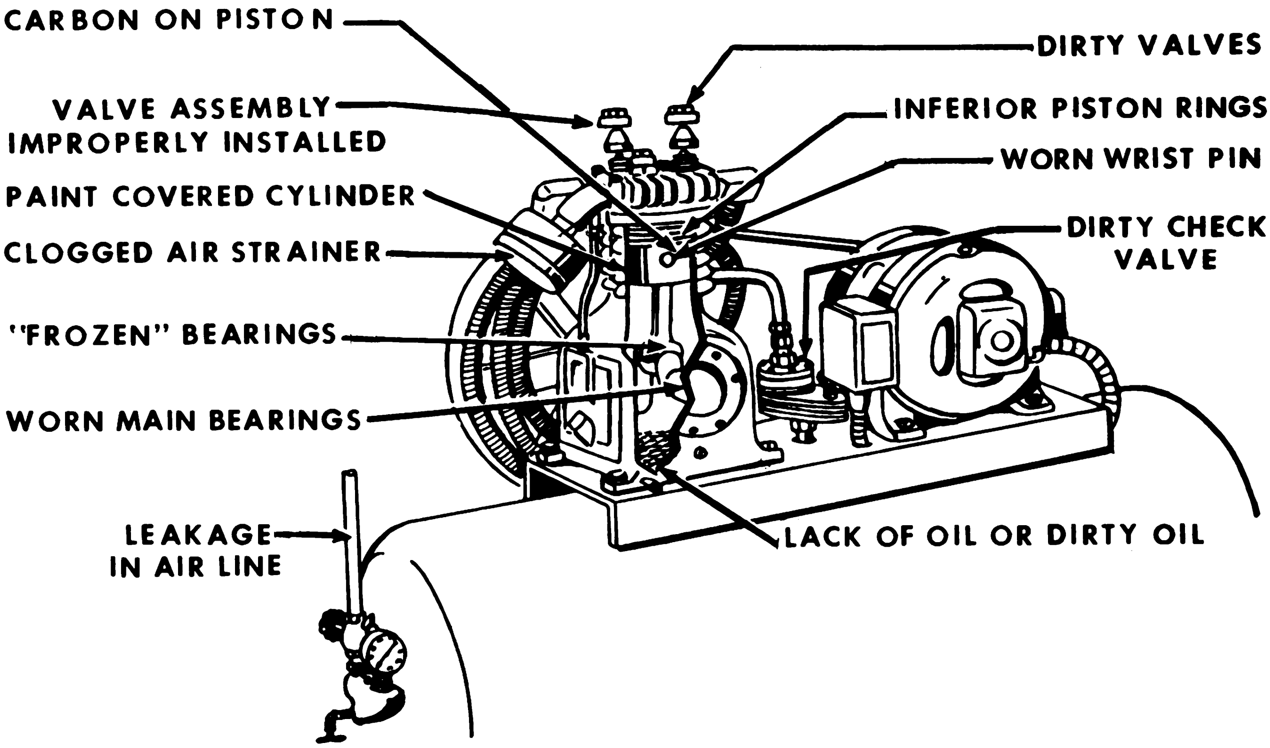

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Figure 13-26.—Common air compressor malfunctions.

Some of the more common causes of air compressor malfunctions are illustrated in figure 13-26. Although the compressor illustrated here is smaller and much simpler in operation to the one previously described, most of the information applies to all air compressors.

CHAPTER 14
HYDRAULIC SYSTEMS MAINTENANCE

Hydraulic systems maintenance includes servicing, performing preoperational and calendar inspections, troubleshooting, repairing, and testing after repair. All of these important tasks, except perhaps servicing and performing preoperational inspections, are accomplished in the Intermediate maintenance activity by the ASH. (In some instances, it may be necessary to utilize Depot maintenance facilities for major and extremely difficult repairs.)

Perhaps the most difficult of these tasks is troubleshooting—locating and diagnosing malfunctions in the hydraulic system by means of systematic checking or analysis. Once the defective component is located, a decision must be made as to the form of repairs. Sometimes the component may be repaired without removal; other times it may be necessary to remove, repair, and reinstall the component; and more often it may be necessary to replace the component and repair the defective component at a later time. Some of the many factors that influence these decisions are the extent of the repair, the availability of replacement parts, the operational commitments for the items of equipment, and the availability of tools, equipment, and qualified personnel.

NOTE: It should be emphasized that an operational check of the system must be performed upon the completion of hydraulic system repair.

As previously stated, troubleshooting is a difficult task. However, with a thorough understanding of the operation of a specific hydraulic system, with the proper use of the applicable schematic and troubleshooting charts, and with a little experience, the ASH can master this task. The knowledge and experience gained from troubleshooting one specific hydraulic system will serve as an aid in troubleshooting other hydraulic systems; however, the applicable Instructions Manual, schematics, and troubleshooting charts must be utilized in all cases.

Some of the typical hydraulic systems found in ground support equipment are described and illustrated in the first part of this chapter. The systems range from the simple systems in hydraulic jacks and workstands to the more complex systems in weapons loaders and test equipment. The discussion covers primarily the operation of the systems with some examples of troubleshooting included. Also included in the last part of the chapter are sections concerning flushing procedures and the control of fluid contamination.

Each hydraulic system requires five basic components, each of which are described in chapter 13. These include a reservoir to provide a supply of fluid, a pump to provide a flow of fluid, lines (tubing and/or flexible hose) to provide a means of transmitting fluid from one component to another, a control (selector) valve to provide a means of directing and controlling the flow of fluid, and an actuating unit to convert the fluid energy to useful work. In addition, of course, a source of power—manual, electric motor, gasoline engine, etc.—must be provided to operate the pump.

HYDRAULIC JACKS

As discussed in chapter 11, the hydraulic jack is frequently used in the maintenance of support equipment. It is also an important item of equipment for the maintenance of aircraft. Certain maintenance of the tires, wheels, brakes, and struts requires part of the aircraft to be lifted off the deck. The entire aircraft must be lifted off the deck to perform such maintenance as operational testing of the landing gear. Some typical hydraulic jacks are described in the following paragraphs.

TYPES

There are several different types and many different sizes (lifting capacity in tons) of hydraulic jacks required for the maintenance of aircraft. The five basic types are illustrated in figure 14-1.

NOTE: In addition to the individual publications available for most models of hydraulic

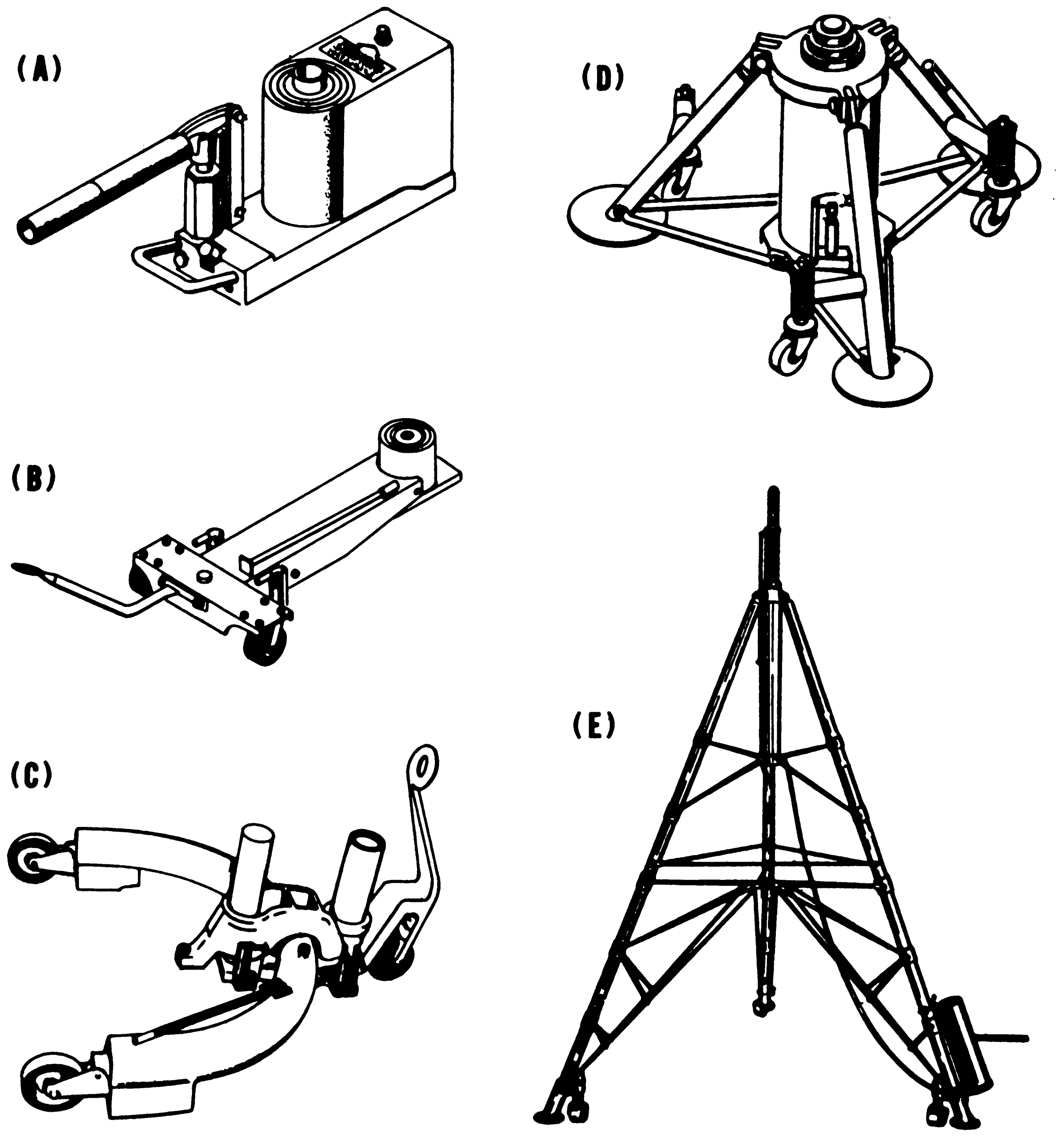

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Figure 14-1.—Hydraulic jacks. (A) Hand axle jack, (B) alligator axle jack, (C) crocodile axle jack, (D) fixed height tripod jack, (E) variable height tripod jack.

jacks, there are two general publications concerning hydraulic jacks that are of interest to the ASH. These are NA 19-70-46, Index and Application Tables for Aircraft Jacks, and NA 19-70-52, Overhaul, Repair, and Test Procedures for Aircraft Hydraulic Jacks. The first of these publications contains a section which lists those jacks that have been approved

and are to be retained in the Naval Aviation Maintenance Program. It lists the jacks by model/part/stock numbers and their application to specific model aircraft. The code numbers of available publications and repair kits are also listed. Another section of this publication lists the jacks that will be deleted from the Naval Aviation Maintenance Program upon depletion of spare parts and repair kits in the supply system. Another section contains an application chart which lists the aircraft by model number and the recommended and alternate models of jacks applicable to the aircraft. A numerical index and a publications index are provided in the last two sections, respectively.

As the title implies, the second of these publications, NA 19-70-52, contains general overhaul, repair, and test procedures for all aircraft hydraulic jacks. It should be used in conjunction with the specific publications which are also listed within this publication.

Hand Axle Jack

The hand axle jack (fig. 14-1 (A)) is a portable self-contained hydraulically operated unit. The hand axle jack is used for raising the main and nose landing gear wheels off the ground or deck so that various maintenance operations may be performed. The lift consists of three rams and an outer cylinder, which is a component or the base of the jack. A rectangular tank is welded to the base, forming the fluid reservoir.

Alligator Axle Jack

View (B) of figure 14-1 illustrates an alligator axle jack. The application of this jack is similar to that of the hand axle jack. The jack is mounted within or on a T-shaped frame assembly with manually operated pressure and speed pumps mounted on the "operating end" of the frame. The lift consists of two rams and an extension screw, all encased within the outer cylinder assembly which is integral with the base. The jack cylinder assembly, with rams, outer cylinder, and base, is hinged and spring supported at the "load end" of the jack frame. The fluid reservoir is a component of the frame assembly.

Crocodile Axle Jack

The crocodile axle jack is illustrated in view (C) of figure 14-1. This jack is used for purposes similar to those of the hand and alligator axle jacks. The lift consists of a lifting arm, with suitable adapter cups to engage the landing gear jack point. The lifting arm is supported by two hydraulic actuating cylinders. The movable cylinders, which move over stationary pistons, are raised simultaneously when the pump is manually operated. These components are mounted on a welded steel frame which contains metal casters. The U-shaped cylinder section portion of the frame serves as the fluid reservoir.

Fixed Height Tripod Jack

View (D) of figure 14-1 shows the fixed height tripod jack. It is a portable self-contained, hydraulically operated jack. This type jack is used for raising the wing, nose, or tail of the aircraft. When used in sufficient numbers and at the required jacking points, jacks of this type are used to lift the complete aircraft off the ground or deck. The jack consists of three principal assemblies—a hydraulic lift incorporating a ram and an external screw, a tubular steel tripod leg structure, and a hydraulic pump assembly incorporated into the base of the hydraulic cylinder. The source of power to raise the cylinder and ram is obtained by manually operating the hydraulic pump.

Variable Height Tripod Jack

A variable height tripod jack is illustrated in view (E) of figure 14-1. This type of jack is used for applications similar to those of the fixed height tripod jack. These two types of jacks are also similar in design; however, the height of the variable height jack may be adjusted by adding extensions to, or removing them from, the legs of the tripod. One other difference is that the hydraulic pump assembly of the variable height jack is mounted on one leg of the tripod.

SYSTEM COMPONENTS AND OPERATION

The hydraulic systems of the different types and models of hydraulic jacks are similar in

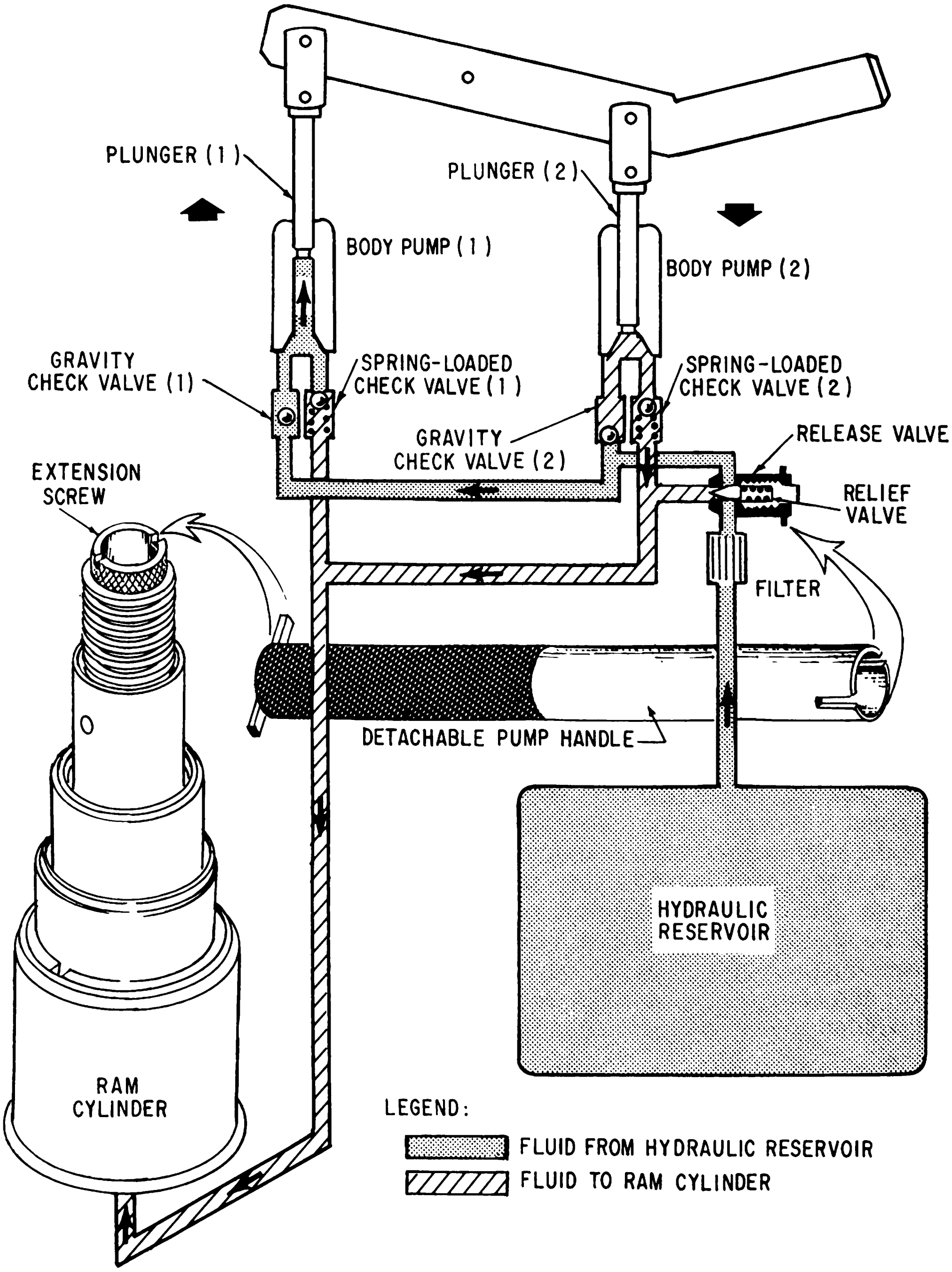

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Figure 14-2.—Jack hydraulic system schematic—dual pump.

operation. As discussed previously, the location of the components may vary in different models. In addition, the type and quantity of certain components differ from model to model. For example, some models are equipped with one single-action hand pump, some are equipped with a dual-action pump operated with one hand lever (fig. 14-2), and others are equipped with two separately operated single-action pumps. Some late model jacks are equipped with a pneumatically operated hydraulic pump in addition to the two single-action hand pumps.

The system illustrated in figure 14-2 contains a dual-action reciprocating pump capable of exerting constant pressure on the jack rams when the handle is moved either up or down. This pump is actually two single-action pumps which are mechanically linked through a pivot arm to one handle. (In those jacks equipped with one single-action pump, fluid pressure is exerted on the jack rams during only one of the two strokes of the handle, usually the DOWN stroke.)

NOTE: The actual system (fig. 14-2) is a compact unit. For example, the four valves are incorporated into one valve assembly, which is situated under the pump plunger in the reservoir. This unit is discussed in more detail in chapter 13.

To raise the jack, first open the air vent (not shown in fig. 14-2) by turning counterclockwise. The air vent functions as a hydraulic fluid fill port, as well as an air vent for the reservoir. Next, close the release valve by turning the T-handle control in a clockwise direction. This can be accomplished with the slotted end of the detachable pump handle. (See fig. 14-2.) The extension screw should then be rotated in a counterclockwise direction until it is extended to the desired height. This can be accomplished by inserting the T-end of the pump handle in the slots at the top of the extension screw. Finally, operate the hand pump with the detachable pump handle until the desired height is reached.

During the raising operation, the downward motion of the jack handle moves the reciprocating plunger (1) upward, forming a partial vacuum (low-pressure area) in the pump body (1). This low pressure causes the gravity check valve (1) to open and, with the aid of spring tension, causes the spring-loaded check valve (1) to close. With atmospheric pressure acting through the air vent on the fluid in the reservoir, the fluid flows from the reservoir into the low-pressure area of the pump (1). During this same downward stroke of the jack handle, plunger (2) moves downward. This force on the fluid closes the gravity check valve (2) and overcomes the spring tension and opens the spring-loaded check valve (2). The fluid then flows out of the pump into the ram cylinder and this force, in turn, raises the rams in the cylinder. A similar action takes place during the upward stroke of the jack handle, except that pump (2) receives fluid from the reservoir and pump (1) forces fluid to the ram cylinder.

The relief valve (fig. 14-2) is often referred to as a safety valve or a safety bypass valve. It serves as a safety factor when a load in excess of the maximum allowable load is applied to the ram cylinder. (The maximum allowable load is 10 percent greater than the rated load. For example, the maximum allowable load for a 15-ton jack is 33,000 pounds.) The relief valve is preset at a pressure that will cause it to open and bypass the fluid back to the reservoir in the event excessive pressure is built up in the ram cylinder. The relief valve is spring loaded and will automatically reseat when the pressure decreases to the preset pressure of the valve.

To lower the jack, turn the release valve counterclockwise, using the slotted end of the jack handle. The distance that the release valve is turned determines the rate of flow of the fluid from the ram cylinder to the reservoir and, therefore, determines the speed of the lowering operation. The rams should be allowed to lower at a slow and even rate of speed.

Figure 14-3 shows the hydraulic system block diagram of a late model 40-ton axle jack. This system operates similar to the one described previously, however, it contains two manually operated pumps and a pneumatically operated hydraulic pump. The pneumatically operated pump is commonly referred to as a pneudraulic pump. Operating either the pneudraulic or manually operated pumps draws fluid from the reservoir into the manifold and supplies the fluid from the manifold through a hose assembly to the actuating cylinder.

The two manually operated pumps are single-action pumps. One is a low-pressure (high volume) pump and the other is a high-pressure (low volume) pump. When raising the jack with the manually operated pumps, commence pumping with the low-pressure pump. The large volume output of this pump raises the jack rapidly. As soon as the force required to operate this pump increases significantly, transfer the jack handle to the high-pressure pump and commence pumping. This pump will raise the jack more slowly, but the force required to operate the pump is markedly less than needed to operate the low-pressure pump. The release valve for these two pumps is located on the high-pressure pump assembly. The relief valve is incorporated in the release valve assembly.

The pneudraulic pump is shown in the insert in figure 14-3. It requires a source of dry air

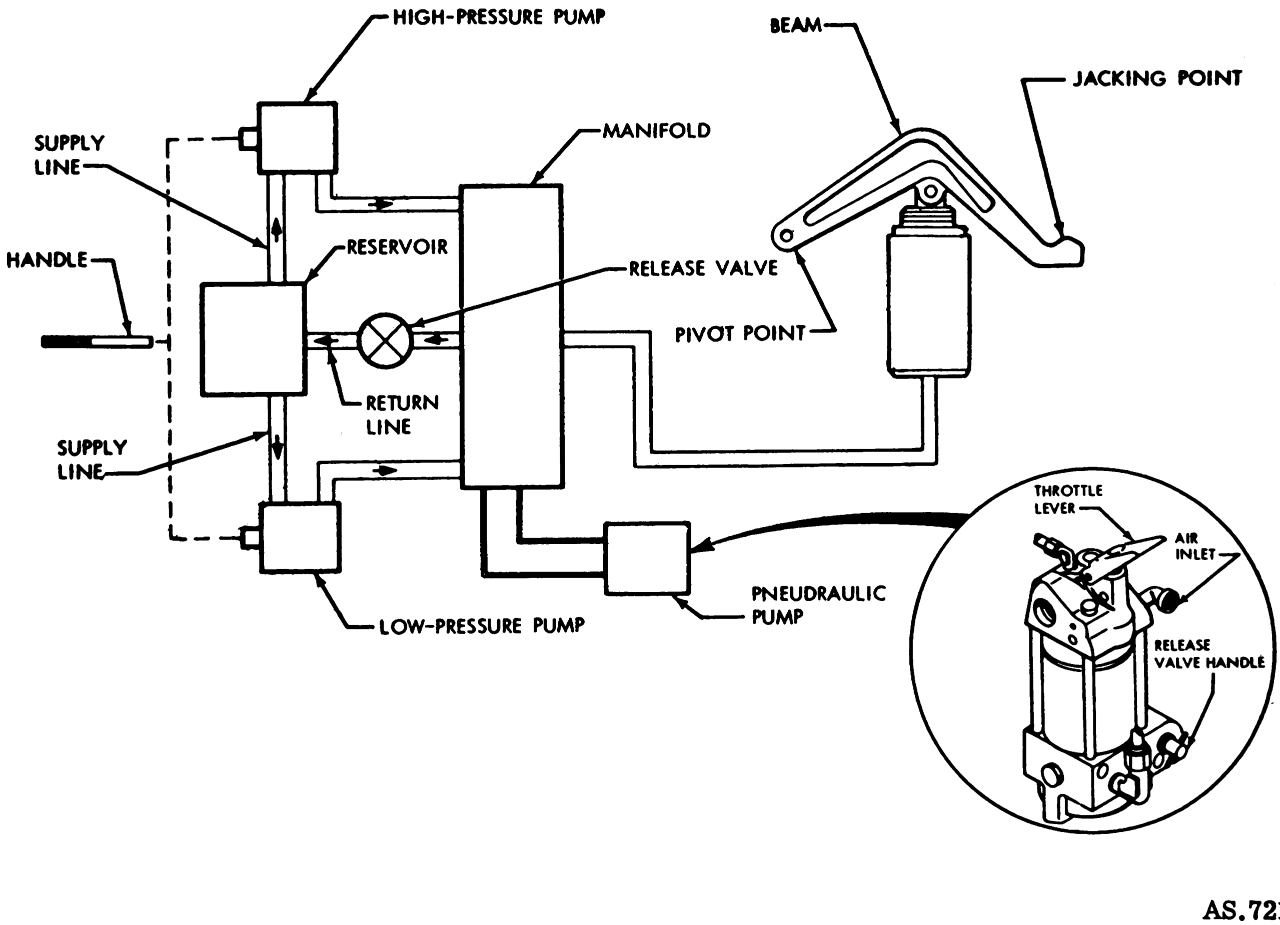


Figure 14-3.—Jack hydraulic system—block diagram.

capable of supplying 90 psi at the jack. To raise the jack with the pneudraulic pump, connect the air supply to the air inlet and open the release valve. Press the throttle lever down and hold it in position until the jack rams are raised to the desired height, then release the throttle lever. The pump will operate rapidly on the initial strokes, becoming less rapid as the hydraulic pressure increases. The jack rams may be lowered by opening the release valve.

MAINTENANCE

The leading causes for failure and malfunction of hydraulic jacks are improper care and improper use of the jacks. Like the majority of ground support equipment, jacks are maintained by AS personnel in the Intermediate activity and are used by personnel of other ratings in the supported Organizational activities. However, the ASH should have a thorough knowledge of the proper use of jacks as he will have many opportunities to advise personnel who use the jacks. Since the ASH must maintain and repair defective jacks, a little information passed on to the user may save several hours of maintenance. The following information is provided to serve as a guide for the ASH in maintaining this type of support equipment:

1. Do not subject jacks to a load beyond the rated capacity. The nameplate located on the jack cylinder provides the recommended maximum tonnage rating of the jack.

2. Jacks should not be left unprotected against the elements. A canvas cover should be placed on top of the jack to prevent moisture from seeping into the internal working parts of the jack assembly.

3. When transporting jacks from areas of storage to the location of operation, a sling should be utilized for hoisting the jack to avoid possible damage. The metal casters provided on the jack assembly may be used for transporting the jacks if the distance is reasonably short.

4. The fluid (MIL-H-5606) must be maintained at the proper level in the reservoir at all times.

5. The threads of the screw extension and the plunger should be coated with a light protective film of lubricating oil to prevent rust and corrosion.

6. Jacks should be stored in a sheltered area to prolong their efficiency and useful life.

Malfunctions of jacks are usually due to obvious defects and the causes are easily determined. Malfunctions of the structural members and mechanisms such as the casters, frame, etc., are usually due to the failure of visible components. Malfunctions of the jacking mechanism may be accompanied by visible leakage or breakage, or may be due to failures that are rapidly determined.

Malfunctions frequently occur in the jacking mechanism with no visible leakage or breakage. The most common of these are (1) the ram assembly does not extend, or (2) does not reach full extension. The probable causes and remedies for these and other malfunctions are usually included in the form of troubleshooting charts in the applicable Operation, Service, and Overhaul Instructions Manual. In addition, a general troubleshooting chart is provided in NA 19-70-52, Overhaul, Repair, and Test Procedures for Aircraft Hydraulic Jacks, which may be used as a guide in troubleshooting all types of hydraulic jacks. However, there are some general procedures which may be followed when troubleshooting most malfunctions of hydraulic jacks. Most of these procedures, which are covered in the following paragraphs, are applicable to most hydraulic systems.

Assume that the rams will not extend. The first question to consider is: What causes the rams to extend from the cylinder? The obvious answer is that hydraulic fluid is the sole item that forces the rams to extend. As the ends of the rams extend farther from the cylinder, more fluid is required to displace the area in the cylinder left by the extending rams. Since hydraulic fluid is the important item, the reservoir should be checked for sufficient fluid. Many manhours have been wasted on the removal and testing of hydraulic system components only to find that insufficient fluid was the cause of the malfunction. If the fluid level is low, the reservoir should be replenished to the proper level with fresh clean hydraulic fluid. Then the jack must be operated several times to assure that the malfunction has been corrected.

NOTE: Loss of fluid from a hydraulic system indicates that there is an external leak at some point in the system. Whenever a system requires an excessive amount of fluid, the entire system must be checked for external leaks. Since most leaks will appear only when the fluid is under pressure, the system should be in operation during this inspection.

If there is sufficient fluid in the reservoir, the next question that must be considered in the troubleshooting procedure is: What can prevent the fluid from flowing into the ram cylinder? Obviously, the pump assembly (including the gravity and spring-loaded check valves) must operate properly. If the pump is operating efficiently, there are other components that could prevent the fluid from entering the cylinder. (See fig. 14-2.) These include the release valve and the relief valve.

Because of its accessibility, the release valve should be eliminated as a probable cause first. If the release valve is not completely closed, the fluid will take the path of least resistance and return to the reservoir.

Once the release valve has been eliminated as a possible cause, the relief valve should be checked. First check the load on the jack rams. If the jack is overloaded, the relief valve will perform its designed function by opening and allowing the fluid from the pump back to the reservoir. If the jack is not overloaded, there are several other probable troubles that could cause the relief valve to remain open or to open too soon. Dirt or other foreign matter between the needle valve and the seat will hold the valve open. A bent or otherwise defective needle or a broken spring will also allow fluid to flow from the pump to the reservoir. Improper adjustment may cause the valve to open too soon.

If dirt or other foreign matter is the cause, the relief valve must be removed and cleaned. This is an indication that the entire system is contaminated with foreign particles. If this is the case, the system should be flushed and replenished with new fluid.

If the needle valve or spring is defective, the valve must be repaired or replaced. After this

as been accomplished, the fluid level in the eservoir should be checked and replenished if ecessary. Whenever a component is removed rom a hydraulic system, there will be some oss of fluid from the system. After such a re-air or replacement is completed, the jack hould be operated several times to assure that he malfunction has been corrected and that here are no external leaks.

If improper adjustment is the cause of the nalfunction, the relief valve must be adjusted. Aost jacks are equipped with a threaded test ort for this purpose. Normally, the test port s closed with a threaded plug. To check and djust the relief valve, remove the plug and in-tall a hydraulic pressure gage in the test port. pply pressure to the system with the hand ump. To obtain the required pressure, a test oad must be applied to the jack rams or, in ome cases, the pressure may be applied with he rams fully extended. The relief valve hould then be adjusted to the pressure listed n the applicable Instructions Manual. Another nethod of adjusting the relief valve is described ater in this chapter.

The pump should be the last component to be onsidered in this type of system. In fact, a efective pump may be so indicated during the heck of other components. For example, if it s impossible to build up system pressure dur-ng the adjustment of the relief valve, it is a ery good indication that the pump is defective. f the pump is defective, it must be repaired or eplaced and the system checked thoroughly.

Although the sequence of steps may differ, he foregoing procedures may be used for roubleshooting other malfunctions of jack hy-raulic systems. As previously mentioned, hese same procedures may be adapted to most ydraulic systems. The components may differ s to quantity, type, and complexity. For ex-mple, instead of a ram cylinder, the actuator nay be a hydraulic motor or a double-action ylinder. Instead of a hand pump, the power ource may be an electrically driven or asoline-engine-driven pump. Instead of a re-ease valve, the control valve may be a sole-oid operated spool type selector valve. The elief valve may be more complex and addi-onal components, such as, an accumulator, egulator, priority valve, etc., may be incor-orated in the system. There may be several ubsystems which operate from one power ystem.

At the present time, there are no established intervals for the inspection of aircraft hydraulic jacks. Some of the applicable technical manuals recommend inspection intervals; others do not. However, a device of this category cannot be inspected too often. Therefore, it is recommended in most applicable technical manuals that a general inspection be performed prior to each use of the jack. This inspection should include the reservoir for adequate fluid, the complete hydraulic system for any evidence of leakage, and all structural members for any signs of cracks.

Aircraft hydraulic jacks should be overhauled at least every 24 months, as recommended by NA 19-70-52, Overhaul, Repair, and Test Procedures for Aircraft Hydraulic Jacks. As its title implies, NA 19-70-52 contains procedures for overhaul and repair of jacks. However, since this manual pertains to all aircraft hydraulic jacks, the information and procedures are of a general nature and serve only as a guide for the basic overhaul and repair of jacks. Therefore, the applicable technical manual should be used in conjunction with NA 19-70-52 for the overhaul or repair of each specific model jack.

Overhaul consists of complete disassembly, inspection, repair and/or replacement of defective parts, reassembly, and test. The general procedures for the overhaul of aircraft hydraulic jacks are as follows:

1. Disassemble the jack in accordance with the procedures listed in the appropriate technical manual.

2. Thoroughly clean all metallic parts with an approved drycleaning solvent, then thoroughly dry each part with low-pressure compressed air or a clean, lint-free cloth.

NOTE: The types of drycleaning solvents and the safety precautions to be observed when handling solvents are discussed in chapter 17.

3. Inspect each part for defects. A list of parts and possible defects is presented in table 14-1. Although this list pertains to the variable height tripod jack, it is applicable, in part, to most other type jacks. In addition to the inspections listed in table 14-1, all components of the jack chassis, the ram assembly, the cylinder assembly, and the lifting arm (on some jacks) should be tested for cracks with the magnetic particle inspection process.

4. Repair or replace all defective parts. All O-rings, backup washers, gaskets, snap-rings, cotter keys, and felt wipers must be

Table 14-1.—Overhaul inspection of aircraft hydraulic jack components.

Part	Inspect for
Chassis	
Extension legs and cross braces	Bends, dents, cracks, out of round holes, distortion
Springs	Distortion
Caster assemblies	Smooth operation (wheels should spin on mandrel without wobble) and gouged threads
Hydraulic assembly	
Extension screw and lock nut	Condition of threads
Inner ram assembly	Burns and scoring
Piston and bushing	Grooving and scoring
Outer ram assembly	Condition of threads, grooving and scoring at OD wear surfaces
Cylinder assembly	Grooving and scoring
Head and base assembly	Grooving and scoring
Pump assembly	
Link and arm assemblies	Out of round holes, distortion
Piston	Grooving, scoring, out of round holes
Body	Grooving, condition of threads
Spring	Distortion
Balls	Nicks, grooves, flat spots
Screen	Breaks in wire, deformation, corrosion
Block assembly	Out of round holes; condition of threads; nicked or scratched valve seat; corrosion

replaced at each overhaul. In most cases, these and other replacement parts are available in the form of repair kits. If available, these kits are listed by part number in the applicable Illustrated Parts Breakdown and can be ordered through supply channels.

If close fitting parts, such as pistons, rams, cylinders, etc., are worn beyond allowable tolerances, replace with new ones. Allowable tolerances of these parts are usually listed in the applicable technical manual.

Defective ball seats in the pump assembly may be refaced with a standard valve seat facing tool. To form a new seat, place a ball of the same size as the original on the seat. Then, using a mallet and a brass dowel, tap the ball lightly until the proper size seat is formed. Discard ball used for seating operation. Install a new ball of the proper size in each refaced seat.

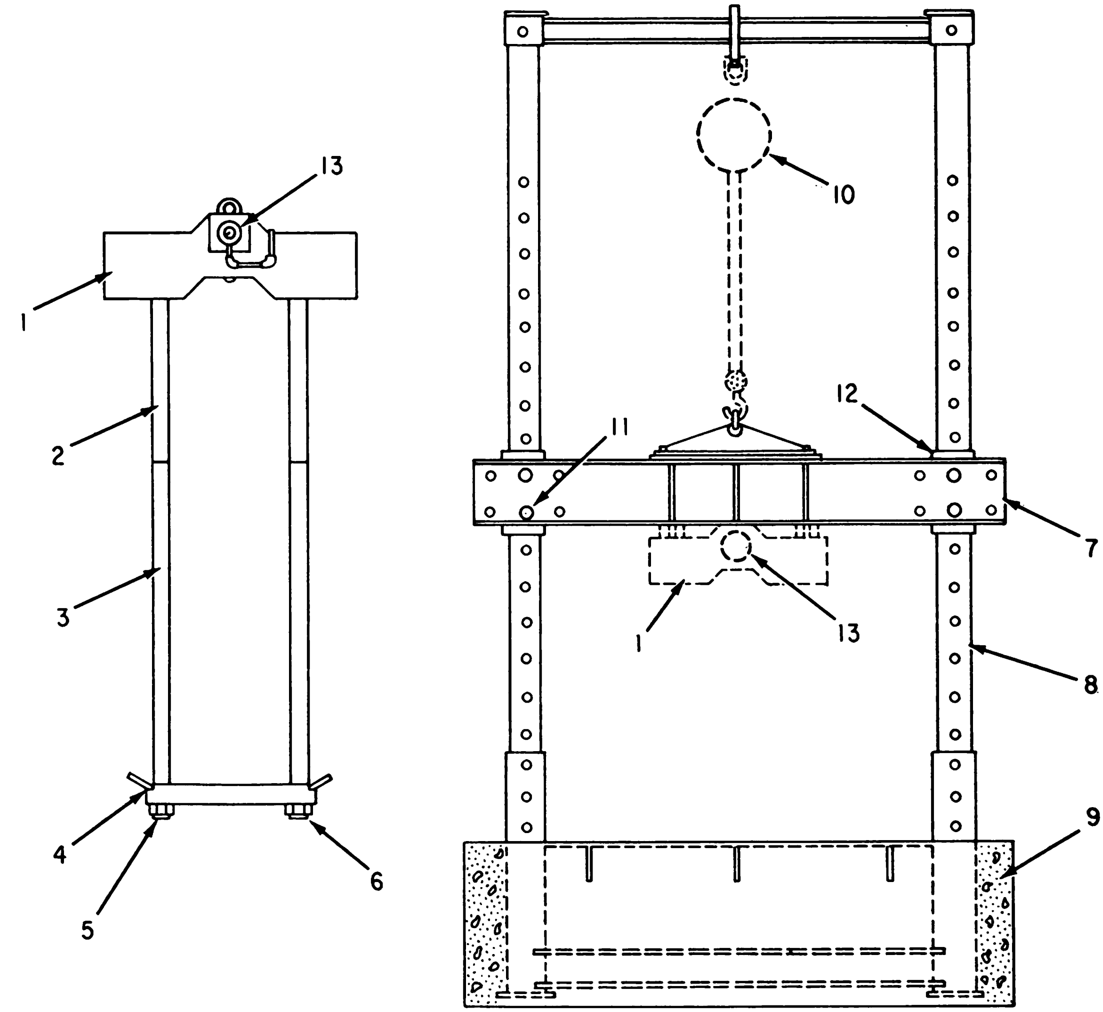
5. Reassemble jack in accordance with the procedures listed in the applicable technical manual. To facilitate installation of hydraulic parts, coat all packings, gaskets, backup washers, and internal parts with hydraulic fluid, MIL-H-5606.

After the jack is completely reassembled, it must be tested. (Testing equipment and procedures are discussed in the next section.) Upon completion of a satisfactory test, spot paint or refinish complete jack assembly, as necessary. Replace stencils, decals, and other required markings in accordance with existing instructions or specifications. Missing or illegible name and data plates must be replaced.

TESTING

As stated previously, the overhaul (rework) of an aircraft jack is not complete until it has been tested. Jacks must also be tested after they have been repaired or modified. In addition, new jacks must be tested when they are received from supply and in-service jacks must be tested at least every 24 months. The testing of jacks is an assigned function of AIMD's and is usually accomplished by personnel of the ASH rating.

A portable or stationary jack tester (fig. 14-4) should be used to test aircraft hydraulic jacks. The construction and operation of these



1. Fixture assembly.	4. Beam assembly.	9. Concrete foundation.
2. Tubular spacers (25 inches).	5. Nut.	10. Chain hoist.
	6. Vertical rods.	11. Tapered pin.
3. Tubular spacers (50 inches).	7. Movable beam.	12. Sleeve.
	8. Vertical columns.	13. Gage.

Figure 14-4.—Aircraft jack testers. (A) Portable; (B) stationary.

testers are described in the following paragraphs. Also included are jack testing procedures.

Portable Jack Tester

The portable jack tester (view (A), fig. 14-4) is an adjustable, self-contained unit. The fixture assembly (1) incorporates a hydraulic capsule, a load gage (reading in tons), and all necessary fittings and connections for measuring imposed loads. The hydraulic capsule provides a bearing surface that will engage the jack socket.

The portable tester will test aircraft hydraulic tripod jack cylinders and conventional

aircraft axle jacks. By use of the different length spacers (2 and 3, fig. 14-4), the tester is adjustable to 25, 50, and 75 inches.

Since adjustment is accomplished through the use of different size spacers, the procedures for assembling the tester differs with the type of jack to be tested. In any case, the first step is to lift the fixture assembly (1) with a chain hoist to the proper height (approximately 97 inches). The remaining procedures for assembling the tester for conventional axle jacks and tripod jack cylinders are described separately as follows:

1. Conventional Axle Jacks. Attach the vertical rods (6) to the fixture assembly (1). Slide the small tubular spacers (2) on the rods (6) followed by the beam assembly (4), the large tubular spacers (3), and the nuts (5). Tighten the nuts securely. Place the axle jack to be tested in the frame with the jack setting on the beam assembly (4) and proceed with test. (Test procedures are discussed later.)

2. Tripod Jack Cylinders. As stated previously, the portable tester is capable of testing only the cylinders of hydraulic tripod jacks. Attach the vertical rods (6) to the hoisted fixture assembly (1), then lower the complete assembly over the tripod jack to be tested. Slide the small tubular spacers (2) and the large tubular spacers (3) on the rods (6) followed by the beam assembly (4) and the nuts (5). Tighten the nuts securely. Center the tripod cylinder on the beam assembly and proceed with the test.

NOTE: Tripod jacks which do not have sufficient clearance between the bottom of the tripod cylinder and the deck for attaching the beam assembly (4) and nuts (5) to the rods (6) should be raised to the desired height by placing blocks under each foot pad. Webs, braces, torque bars, or any part of the tripod jack that prevents the proper positioning of the beam assembly (4) under the tripod cylinder should be repositioned on the jack or removed. When test is completed, reassemble the jack to the proper configuration.

Stationary Jack Tester

This type tester (view (B), fig. 14-4) is a stationary, self-contained, adjustable unit which utilizes that same fixture assembly (1) as the portable tester. The fixture assembly is attached to a movable beam (7) which is captive to two vertical columns (8) fixed in a floor level concrete foundation (9). The movable beam can be repositioned in height to accommodate all aircraft hydraulic jacks. This stationary tester may also be used for testing other load lifting ground support equipment with capacities up to and including 55 tons (110,000 pounds).

To prepare the stationary tester for operation, lift the movable beam (7) and fixture assembly (1) with a chain hoist to the height which will accommodate the jack to be tested. At the desired height, align holes on the movable beam (7) with the holes on the vertical columns (8). Slide the tapered steel pins (11) through the aligned holes. Place the jack under the fixture assembly and proceed with the test.

Maintenance of Jack Testers

Before proceeding to jack testing procedures, emphasis should be placed on the care and maintenance of the jack tester. Like the jacks it is designed to test, the jack tester must perform safely and satisfactorily each time it is used. Therefore, a general inspection is a must prior to each use of the tester, paying particular attention to any signs of structural cracks or traces of leakage. In addition, the tester must be inspected in detail at least every 90 days. This inspection should include the following:

1. Inspect the hydraulic cylinder, lines, fittings, and pressure gage for deterioration, leakage, and loose connections.
2. Inspect all structural members and welds for cracks or any evidence of binding when in motion. Inspect the concrete foundation of stationary testers for major cracks running from the vertical columns.
3. Inspect all attaching parts for looseness or stripped threads.

Should either the preuse or 90-day inspection reveal any discrepancies that affect the capabilities of the tester, they should be corrected before the tester is used. The sleeves (item 12, fig. 14-4) should be lubricated as needed to insure easy positioning of the movable beam on the vertical columns of the stationary tester.

A functional test must be performed on the tester at 12-month intervals. This is accomplished by applying calibrated loads of 10, 30, and 55 tons on the tester. The gage (13) should hold its reading for 5 minutes at each of these loads. No leakage of hydraulic fluid or malfunctions should occur during this time. The

uracy of the gage should be within 2 percent ull range.

k Testing Procedures

In preparing a jack for testing, the following ps should be performed:

1. Check the hydraulic fluid level in the k. (The proper fluid level for the most efent operation is 1/2 inch below the filler g port when the rams are completely rected.) Replenish the system with hydraulic d, Specification MIL-H-5606, if required.

2. Operate the jack with no load applied unhe rams are fully extended. During this option, the action of the pump handle should solid on each power stroke. Open and close release valve often while retracting the ns. Rams of large jacks should fully retract their own weight. A force of approximately pounds is required to retract the rams of aller jacks.

3. Properly place the jack in the preaded tester. Extend the extension screw (of ks so equipped) until the internal stop prets further extension. Then, operate the jack il the jack point bears on the jack pad of the ure assembly.

NOTE: At this point in the testing proceds, it may be necessary to bleed any accumuon of air from the hydraulic system of the k tester. A bleed plug is provided on the ure assembly for this purpose. To bleed system, loosen the bleed plug and extend the k. This will force any air in the system the reservoir of the tester. Replenish the tem of the tester with hydraulic fluid, MIL-5606, if necessary.

The complete testing operation consists of tests—a relief valve test and a proofload t. These procedures are discussed in the owing paragraphs.

RELIEF VALVE TEST.—As explained preusly, the relief valve should be adjusted to n and bypass fluid back to the reservoir en a load in excess of the maximum allowe load is applied to the jack. This relief ve setting can be tested and correctly added through the use of the jack tester. The cedures for this test are as follows:

1. With the jack properly positioned in the ter, operate the jack until the last stage ram partially extended and the pressure gage of tester begins to register. Make certain that jack is positioned properly in the tester at times. If, at any time during the testing operation, the jack is not positioned properly, release the hydraulic pressure and reposition the jack before resuming the test.

2. Continue operating the jack until the rated load is indicated on the pressure gage.

3. Vent the reservoir of the jack to release any trapped air in the system.

4. Continue operating the jack, increasing the load to the maximum allowable load (10 percent above the rated load). At this time, observe that the relief valve is operating. This is indicated by the "soft" action of the pump handle. Also observe that the pressure on the gage does not decrease or increase. There should be no leakage of hydraulic fluid at any point.

NOTE: If the pressure gage fails to indicate the maximum allowable load, the setting of the relief valve is too low. If the reading of the pressure gage continues to increase after reaching the maximum allowable load, the setting of the relief valve is too high. If either of these situations is indicated by the test, the relief valve must be adjusted accordingly. To increase relieving pressure, turn the relief valve adjusting screw clockwise; to decrease relieving pressure, turn the adjusting screw counterclockwise.

PROOFLOAD TEST.—To conduct a proofload test, the jack and tester are prepared in the same manner as described previously. With the jack properly positioned in the tester, proceed as follows:

1. Operate the jack until its rated load is registered on the pressure gage. The jack should be capable of imposing this load without exerting more than 75-80 pounds of force on the jack handle.

2. Visually inspect the pump packing and the ram and cylinder assemblies for evidence of leakage. There should be no evidence of leakage at any point.

3. Inspect for distortion, bending, and swaying motion or permanent set in the ram or screw extensions. None should be evident.

4. Inspect legs, leg extensions, torque bars, leg braces, brace webs, nuts, bolts, foot pad assemblies, casters, and all other structural parts for cracks, dents, elongated bolt holes, wear, distortion, and general condition. All braces or brace webs having bolt holes elongated in excess of 1/32 inch should be replaced.

5. Inspect hydraulic hose, tubing, and connections for leaks, wear, and general condition. Tighten and/or replace, as required.

6. Check operation of the ram locking devices by manually rotating the ram lock to ascertain that it rotates freely up and down the ram. Ram locking devices which are equipped with retaining screws are checked by rotating the ram nut to the top of the ram. The locknut must fall freely under its own weight. When tightened, the retaining screw must secure the locknut any place on the ram.

7. The jack should hold the rated load at any point of the ram extension. The settling rate should not exceed 0.020 inch per half hour.

8. Upon completion of the test, raise the ram locknut (if the jack is so equipped) to the top of the ram, slowly open the jack release valve by turning it counterclockwise, and lower the screw extension by turning it clockwise. As explained previously, the rams of large jacks should settle by their own weight; those of smaller jacks require a force of approximately 50 pounds.

9. The failure of any part to perform satisfactorily must be investigated and corrected by necessary rework. After the required rework has been accomplished, the entire testing procedure must be repeated.

WORKSTANDS

As stated in chapter 4, there many types of workstands required to perform maintenance on the various types and models of aircraft. Some workstands are fixed in regard to height; however, most of the stands in present use are the adjustable type. The height of some workstands is adjusted manually and some are adjusted electrically; however, the most common types are adjusted hydraulically. Some of the most common types of hydraulically operated workstands are discussed in the following paragraphs.

TYPES

Perhaps the most common type of workstand is the B-4A Aircraft Maintenance Platform described and illustrated (fig. 4-21) in chapter 4. Also in this group are the B-5 and B-5A workstands, which are similar to the B-4A in design and operation. Another type of hydraulically operated maintenance workstand is illustrated in figure 14-5.

The B-1 workstand (view (A), fig. 14-5) consists of a stair structure and work platform mechanically linked together in such a way as to enable both (stairs and platform) to remain level throughout the height range of the stand. Stair support members and handrails are rigged in such a manner to make them self-aligning at all platform levels. Because of the handrails on both the stairs and the work platform, this stand enables personnel to work at various heights in relative safety.

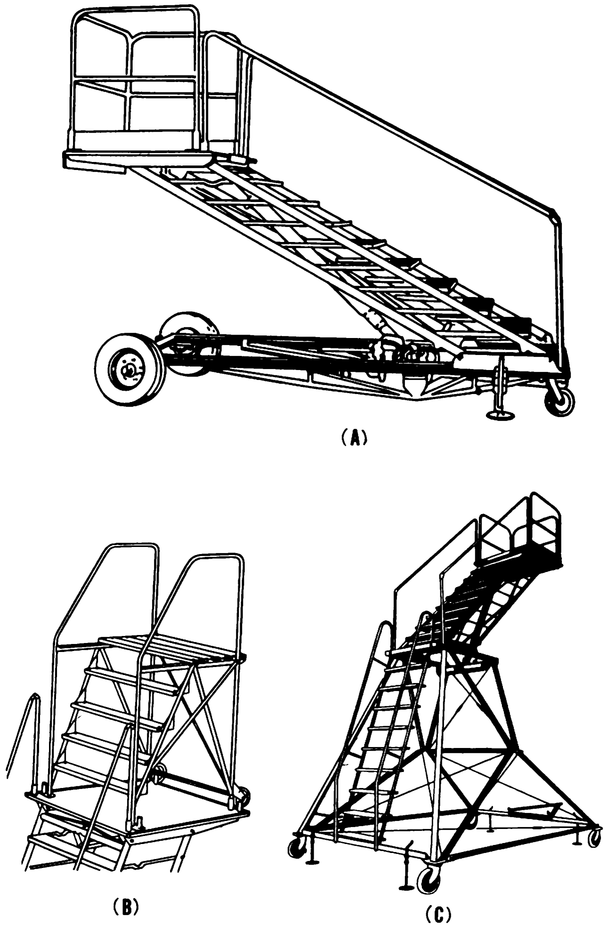


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Figure 14-5.—B-1 and B-2 maintenance workstands.

Special provisions are made for extending the B-1 platform height by an additional 4 feet. This is accomplished by placing another stand (view (B), fig. 14-5), into the platform post sockets, which are designed to accommodate this additional structure. The post sockets on

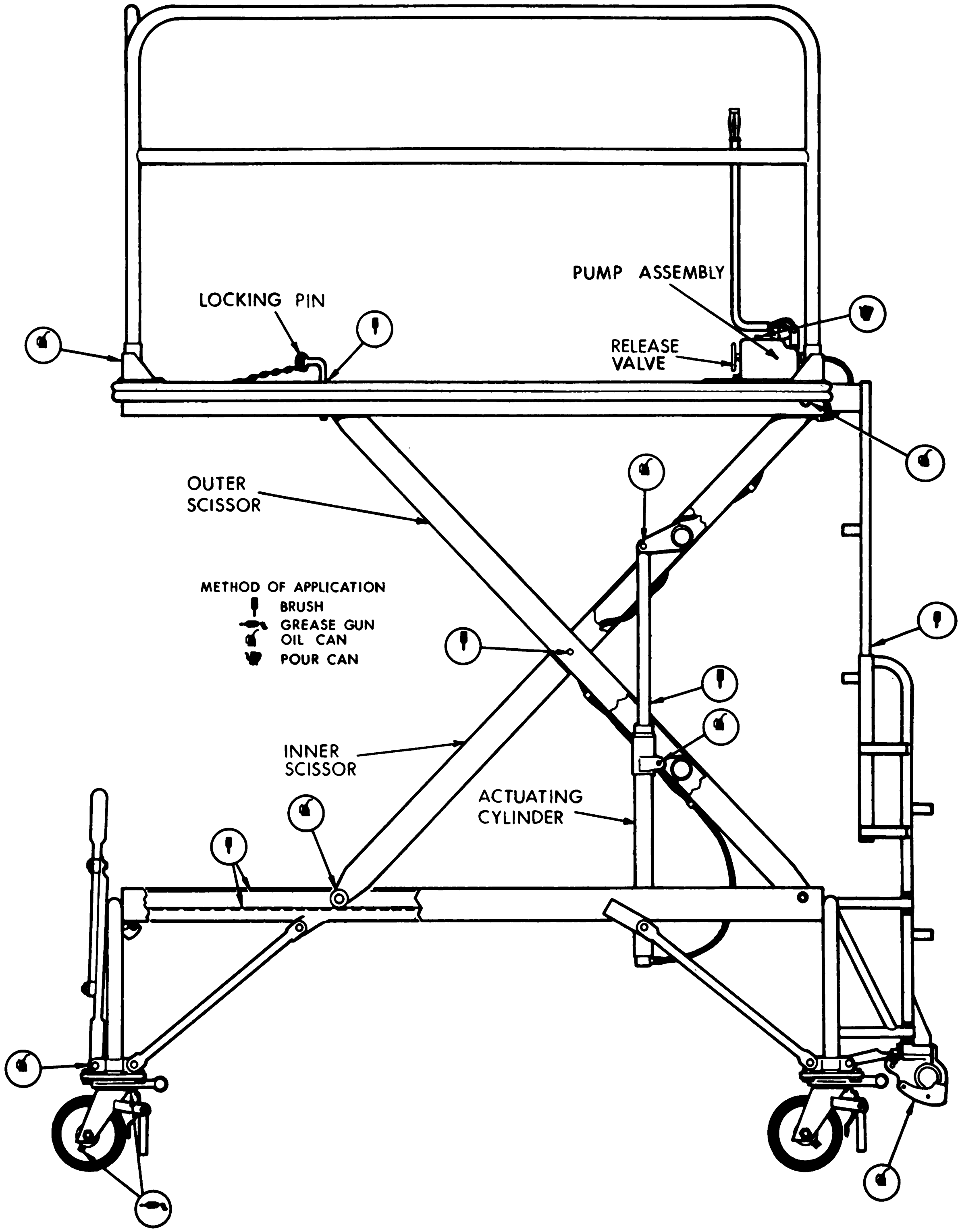

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Figure 14-6.—B-4A maintenance platform—operation.

the B-1 platform provide for either the attachment of platform handrails or installation of the extra stand for greater height.

The B-2 maintenance stand (view (C), fig. 14-5) is the B-1 stand permanently mounted on a base extension structure of fixed height. The extension base, fabricated of angle iron and steel tubing, is 10 feet in height. This arrangement results in a maintenance stand which has a base structure of fixed height and an upper stair structure and work platform which can be hydraulically varied in height.

SYSTEM COMPONENTS AND OPERATION

The hydraulic systems of the workstands described in the previous paragraphs are similar in operation. However, the type and arrangement of the components differ to some extent. Figure 14-6 shows the arrangement of the components of the B-4A workstand. Also shown in the illustration are the points on the stand that require lubrication and the method of application.

The B-4A hydraulic system is similar to the jack hydraulic system (fig. 14-2) except that the actuator is a single ram (piston) instead of the telescoping rams in the jack system. The B-4A system contains only one single-action pump. Like the jack system, this system is very compact. The pump, the reservoir, and the valve assembly (gravity check valve, spring-loaded check valve, relief valve, and release valve) are combined into one unit. This unit is indicated as the pump assembly in the illustration. The pump assembly is connected to the actuating cylinder with flexible hose.

The cylinder of the actuator is anchored (free to swivel) to a brace between the two outer scissors of the scissors assembly, and the piston rod is anchored (free to swivel) to a brace between the two inner scissors. One end of each of the outer scissors is hinged on the lower frame of the stand, and the other ends are free to slide in a track under the platform. There are several holes in the tracks for insertion of the locking pins. The inner scissors are hinged to the platform and are free to slide in tracks on the lower frame. The inner and outer scissors are hinged to each other in the center. The extension of the piston rod opens the scissors assembly and the retraction of the piston rod closes the scissors assembly, causing the platform to raise or descend.

The locks on the swivel casters should be depressed before attempting to raise the platform. Then close the release valve by turning it clockwise. Next operate the hand pump until the platform reaches the desired height. Finally, install the lockpins in the appropriate holes in the tracks.

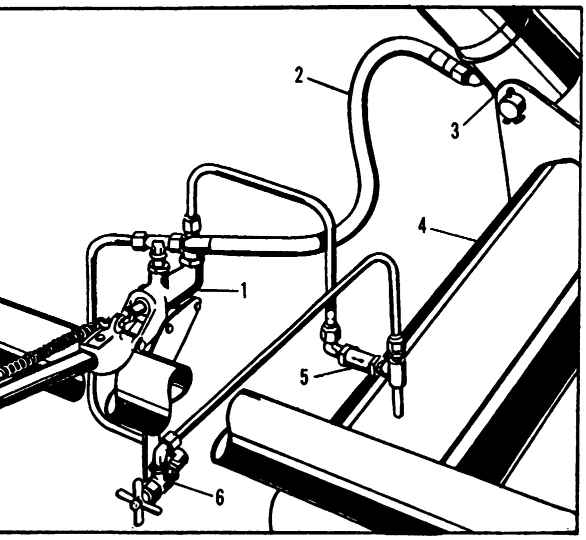
Before the platform is lowered, it should be raised slightly to remove any load from the lockpins. Then remove the lockpins from the holes and open the release valve. The speed of descent of the platform is controlled by the degree the release valve is opened. When the platform is completely lowered, the locks on the swivel casters may be released so that the stand may be moved.

The B-1 hydraulic system is illustrated in figure 14-7. Although this system operates similar to the B-4A system, the arrangement of the components is quite different. The hand pump, the reservoir, and the release valve are each separate units.

The height variations of the B-1 workstand are controlled by the extension and retraction of the piston ram of the hydraulic cylinder assembly. The cylinder assembly is equipped with a safety lock. This lock is a U-shaped steel device designed to fit into grooves cut into the outside cylindrical housing of the cylinder assembly. The lock is attached to the cylinder assembly with a length of chain to prevent it being lost or otherwise separated from the maintenance stand. This lock prevents movement of the ram in the event of hydraulic failure. It should be installed before ascending the stairs to the platform.

To raise the stand, the release valve (6) must be closed. By actuating the hand pump, hydraulic fluid is forced from the reservoir (4) through the hose (2) to the cylinder assembly (3). This causes the ram to extend, raising the platform and stair assembly.

The release valve (6), when in the closed position, confines hydraulic fluid pressure to the cylinder assembly. The same valve, when opened, allows the hydraulic fluid to bypass the pump and flow from the cylinder assembly to the reservoir. Pressure thus removed from the cylinder allows it to retract. The speed of retraction is controlled by the degree of the release valve opening. A removable screen strainer (5), located in the supply line from the reservoir to the pump, serves to prevent abrasive particles from entering the pump.



AS.725

. Hand pump.
. Connecting hose.
. Actuating cylinder.
4. Reservoir.
5. Strainer.
6. Release valve.

Figure 14-7.—Hydraulic system—
B-1 maintenance workstand.

The extension or retraction of the ram oves the stair support assembly, which consts of two oblong box sections fabricated of ılded steel tubing. These two sections form flexible parallelogram linkage and are atched by pivot pins to the base assembly at the ttom and to the platform at the top. The airs are mounted between these two sections such a manner that they will remain parallel the base frame at all platform levels. The air handrail posts are hinged at the top to ep the handrails parallel to the stair support ames at all times.

The hydraulic system components of the B-2 and, including the cylinder assembly, are entical to those of the B-1 stand. The system stallation is also similar and varies only beuse the location of some hydraulic system mponents is different. In this system, the draulic fluid reservoir is mounted near the draulic cylinders assembly on top of the exnsion structure. A general change in the inallation of the hydraulic lines and connections .s made to allow the hand pump and the release valve to be mounted on the lower rectangular base of the stand. This permits operation of the hydraulic system from ground level. However, despite these changes, the principle of operation of the hydraulic systems remains unchanged.

MAINTENANCE

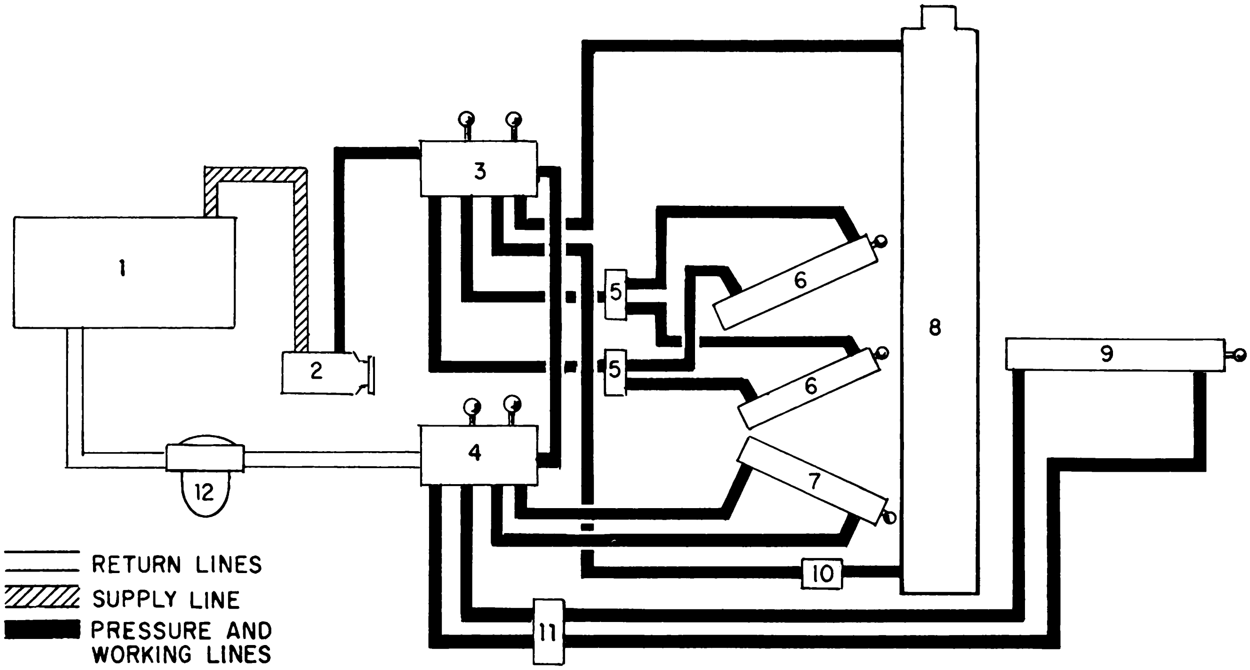
Workstands require periodic inspections and servicing to insure safe and dependable service. Only by complying with the inspection intervals and maintenance procedures established in the applicable Instructions Manual and applicable Maintenance Requirements Cards can satisfactory operation of this equipment be expected. The hydraulic systems of these workstands are maintained in much the same manner as the jack systems described previously. The same general troubleshooting procedures may be used to determine the cause of malfunctions in these systems.

Particular attention should be paid to the lubrication of workstands. Proper and frequent lubrication not only aids in the prevention of corrosion, but reduces the friction between moving parts. For example, notice the lubrication points of the B-4A workstand illustrated in in figure 14-6. Reduction of friction at the pivot points and slides reduces the force necessary to raise the platform. This reduction in friction, in turn, reduces the pressure required of the hydraulic system. The lubrication data is included in the applicable Instructions Manual.

FORKLIFT TRUCKS

Forklift trucks are described and illustrated in chapter 4. Although most of the forklifts used in aviation maintenance activities are powered by gasoline or diesel engines, some are electrically operated. In any case, the fork is raised, lowered, tilted, etc., by hydraulic power.

Forklifts are equipped with a hydraulic cylinder to raise and lower the fork and one or two cylinders to tilt the upright. The tilt cylinders provide the means whereby the fork and upright may be tilted forward for loading and unloading, and tilted aft to stabilize the load while transporting it. In addition to these cylinders, some forklifts are provided with a hydraulic cylinder which supplies power to move the carriage laterally to facilitate manipulation of the fork in confined areas.



AS.726

1. Reservoir.
2. Pump.
3. Control valve (lift and tilt).
4. Control valve (shift and telescopic boom).
5. Manifolds.
6. Tilt cylinders.
7. Shift cylinder.
8. Lift cylinder.
9. Telescopic boom cylinder.
10. Orifice check valve (restrictor).
11. Quick disconnects.
12. Filter.

Figure 14-8.—Forklift hydraulic system schematic.

Frequently, loads that could be lifted and transported with forklifts are inaccessible to the forks or must be lifted with chains or wire ropes. As a result, some forklifts are provided with a detachable telescopic boom. The boom may be attached to the upright in place of the forks. A hydraulic cylinder on the boom supplies the power to extend and retract the boom to permit accessibility to the load. The chains or wire ropes required to lift the load are attached to a hook at the end of the boom. The cylinder is connected to the hydraulic system by suitable flexible hose and fittings. The control valve is a permanent part of the hydraulic system.

Several models of forklifts are equipped with power steering and a few are equipped with power brakes. These systems usually receive their source of power from the main hydraulic system. Power steering systems are discussed in chapter 16 and power brake systems are covered in chapter 15.

Most of the hydraulic cylinder assemblies on forklifts are the double-acting type; that is, fluid must be applied to either side of the piston to provide movement in the corresponding direction. However, the lift cylinder on some models is the single-acting type. This type operates similar to the cylinder assemblies of the hydraulic jack and the workstand previously described. Fluid under pressure is required to raise the piston in the cylinder. When this pressure is released through the control valve, the weight of the fork, loaded or not, will lower the piston in the cylinder.

SYSTEM COMPONENTS AND OPERATION

Figure 14-8 illustrates an example of a forklift hydraulic system schematic. This schematic is intended for the purpose of training and may not duplicate any particular model.

[H]owever, some of the features included in this [s]ystem are found in all forklift hydraulic [s]ystems.

This type system is referred to as an open-[c]enter system. An open-center system is one [h]aving fluid flow, but no pressure in the sys-[t]em when the actuating mechanisms are idle. [T]he pump circulates the fluid from the reser-[v]oir, through the control valves, and back to [t]he reservoir. The control valves in an open-[c]enter system are always connected in series [w]ith each other, an arrangement whereby the [p]ressure line goes through each control valve. [F]luid is always allowed free passage through [e]ach control valve and back to the reservoir [u]ntil one of the control valves is positioned to [o]perate a mechanism. Fluid is then directed [f]rom the pump through one of the working lines [t]o the actuator. Pressure then builds up in the [s]ystem and provides the necessary force to [m]ove the actuator. The fluid from the other [e]nd of the actuator returns to the control valve [t]hrough the opposite working line and flows [b]ack to the reservoir.

The pump (2, fig. 14-8) is a constant-[d]isplacement pump. On engine-driven fork-[l]ifts, the pump is usually mounted on the trans-[m]ission assembly and receives its power from [t]he engine through the transmission. On elec-[t]rically driven forklifts, an electric motor is [u]tilized to drive the pump. Gear pumps are [n]ormally used in these systems; however, vane [t]ype pumps are used on some models. With the [e]ngine running, the pump provides a flow of [f]luid to the control valves.

The control valves (3) and (4) are actually [f]our individual control valves. The lift control [v]alve and the tilt control valve are constructed [a]s one assembly, and the shift control valve [a]nd the telescopic boom control valve are con-[s]tructed as one assembly. However, each valve [o]perates independently of the others. Each [c]ontrol valve contains a relief valve. The re-[l]ief valve protects the pump from any overload [o]f pressure. For example, if the pressure in-[c]reases due to an overload, or due to an actu-[a]tor extending or retracting to the end of its [s]troke, the relief valve opens and the fluid is [t]hen allowed to bypass and return to the [r]eservoir.

To raise the forks, the lever of the lift con-[t]rol valve is moved aft. This directs the fluid [f]rom the pump to the bottom of the lift cylinder [(]8) and directs the flow from the top of the [c]ylinder back to the reservoir. The orifice check valve (10) allows free flow during the raising operation. However, during the lowering operation, the orifice check valve restricts the flow, thus preventing the load on the forks from forcing the piston of the lift cylinder to lower too fast. Flow regulators are used in some systems for this purpose. The forks are lowered by positioning the control valve in the forward position, allowing the fluid to flow in the opposite direction.

To tilt the upright, move the tilt control valve lever. This directs the flow of fluid from the pump to one of the manifolds (5) where it is split into two lines and flows to the corresponding ends of the two tilt cylinders. The fluid from the opposite ends of the actuating cylinders flows through the other manifold, through the control valve, and back to the reservoir.

The shift system and the telescopic boom system operate similar to the lift system. The quick-disconnect fittings (11) are provided for convenient attachment and detachment of the telescopic boom.

A filter (12) is incorporated in the return line. The filter is a full flow type; that is, all fluid flows through the filter element. A relief valve is incorporated in the top of the filter assembly. In case the filter element becomes clogged and causes pressure to build up in the return line, the relief valve opens and allows the fluid to bypass the element and flow directly to the reservoir.

MAINTENANCE

The maintenance of the forklift hydraulic system includes periodic inspections, servicing, and repair. The inspection intervals and procedures are included in the Operation and Service Instructions. Inspection consists mainly of checking for external leaks, damaged tubing and flexible hose, loose fittings, etc. Particular attention must be paid to the type of fluid used for servicing the system. Although most hydraulic systems in support equipment require MIL-H-5606 fluid, some systems that supply fluid for power steering and power brakes require a different fluid. The applicable Instructions Manual should be consulted for the correct fluid specification.

Although the forklift hydraulic system is more complex, the troubleshooting procedures outlined for the hydraulic jack can be adapted to this system. Instead of one release (control)

valve which directs flow to and from one actuator in the jack system, there are four control valves which direct flow to four actuating systems (subsystems) in the forklift system. One other difference is the actuating cylinders. The forklift system contains double-acting cylinders rather than the single-acting cylinders in the jack and workstand systems. Some of the leaks that appear as external leaks in single-acting cylinders are internal leaks in double-acting cylinders. Defective piston seals will allow fluid to flow from the pressure side of the piston to the return side and return to the reservoir.

If one of the subsystems (for example, the lift system) fails to operate, first check the operation of the other subsystems. If they fail to operate, the trouble is probably in the power system. (The power system includes those components necessary to supply fluid to the control valves. In this case, the power system includes the reservoir and the pump.) The fluid level in the reservoir should be checked first. Next, check the output of the pump.

If the other subsystems operate normally, the malfunction is probably due to an internal leak in the lift actuating cylinder or the lift control valve. Similar procedures may be used to determine the cause of malfunctions in the other subsystems.

AIRCRAFT SPOTTING DOLLY

The purpose, capabilities, and differences of the SD-1C and SD-1D spotting dollies are described in chapter 4. Although some of the hydraulic components are manufactured by different companies, the operation of the hydraulic systems of the two models is identical. A schematic diagram which is applicable to the hydraulic systems of both models is illustrated in figure 14-9.

The spotting dolly actually contains two hydraulic systems—the hydrostatic transmission and the lifting linkage control system. The hydrostatic transmission consists of two variable displacement hydraulic pumps which drive two fixed displacement hydraulic motors. In turn, each motor drives one of the two driving wheels through reduction gears and axle shaft.

NOTE: The number-letter combinations (3a and 3b, 4a and 4b, etc.) in figure 14-9 refer to identical components for the left and right drives, respectively. Except where necessary, only the number identification is used in the following discussion and is applicable to either drive.

A complete pump unit includes a charge pump (3), two check valves (4), and a variable displacement pump (5). The charge pump and check valves are actually built into the cover of the variable displacement pump. The unit is driven by the engine through a gearbox.

The complete motor unit includes a fixed displacement axial piston motor (7) and fluid controls (8). The fluid controls include high- and low-pressure relief valves and a shuttle valve. These valves are built into the motor cover.

The inlet and discharge ports of the pump (5) are connected by the high- and low-pressure lines (6) to the discharge and inlet ports of the motor (7). The ports of the pump alternate as discharge and inlet ports, depending upon the direction of flow through the system. Therefore, the lines (6) alternate as high-pressure and low-pressure lines, and the ports of the motor alternate as inlet and discharge ports. The direction and rate of flow are controlled by the operating control on the pump. This is a servo valve which is controlled through mechanical linkage by a control handle near the operator. Movement of the servo valve moves the variable cam in the pump.

When the variable cam is in neutral, there is no flow from the pump. When the cam is moved from neutral, fluid is discharged through one of the ports of the pump. This fluid flows through one of the lines (6) to one of the ports of the motor (7). Under this condition, this is the high-pressure side of the system. The flow of fluid through the motor causes the motor shaft to rotate in one direction. The fluid discharged through the motor discharge port flows through the opposite line (6) to the inlet port of the pump. Under this condition, this is the low-pressure side of the system. This fluid continues to cycle between the pump and motor. The speed of the motor may be increased by increasing the rate of flow from the pump. This is accomplished by moving the variable cam farther from neutral.

Moving the pump control and, therefore, the variable cam, to the opposite side of neutral reverses the flow of fluid through the system. This reverses the high- and low-pressure sides of the system and, therefore, reverses the direction of rotation of the motor shaft.

Fluid is supplied from the reservoir (1), through the filter (2), to the charge pump (3).

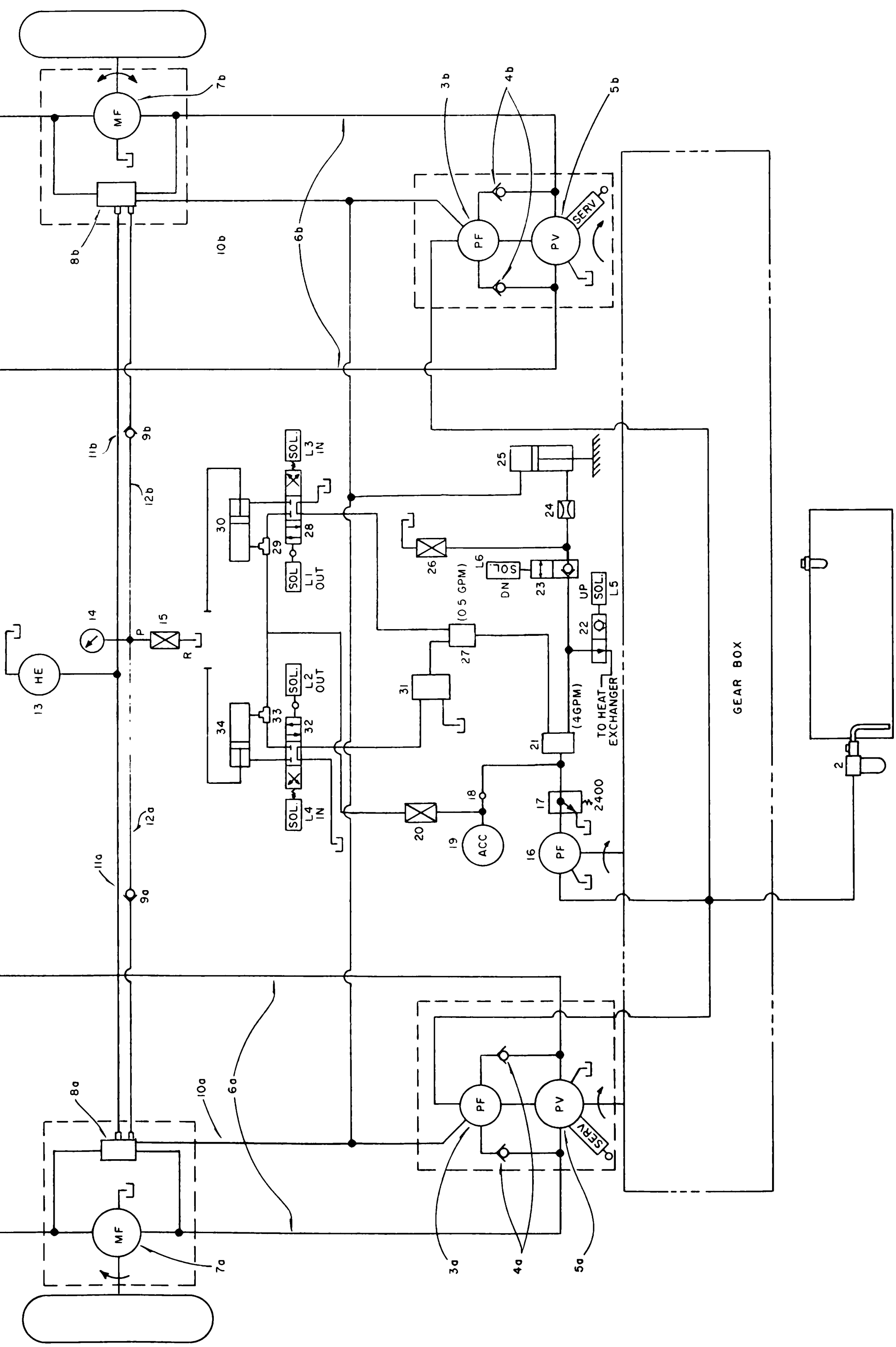


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Figure 14-9.—SD-1C/SD-1D hydraulic system schematic.

Nomenclature for figure 14-9.

1. Reservoir.
2. Filter.
3a. Charge pump.
3b. Charge pump.
4a. Check valves.
4b. Check valves.
5a. Axial piston pump.
5b. Axial piston pump.
6a. High- and low-pressure lines.
6b. High- and low-pressure lines.
7a. Hydraulic motor.
7b. Hydraulic motor.
8a. Fluid controls.
8b. Fluid controls.
9a. Check valve.
9b. Check valve.
10a. Low-pressure return line.
10b. Low-pressure return line.
11a. Low-pressure return line.
11b. Low-pressure return line.
12a. High-pressure line.
12b. High-pressure line.
13. Heat exchanger.
14. Pressure gage.
15. Transmission selector valve.
16. Gear pump.
17. Relief valve.
18. Check valve.
19. Accumulator.
20. Shutoff valve.
21. Flow divider.
22. Control valve, lift cylinder UP.
23. Control valve, lift cylinder DOWN.
24. Flow control valve.
25. Lift cylinder.
26. Shutoff valve.
27. Flow divider.
28. Control valve, right-hand lifting arm IN and OUT cylinder.
29. Shuttle valve.
30. Right-hand lifting arm IN and OUT cylinder.
31. Flow divider.
32. Control valve, left-hand lifting arm IN and OUT cylinder.
33. Shuttle valve.
34. Left-hand lifting arm IN and OUT cylinder.

This is an internal gear type pump. Fluid is discharged from this pump through one of the two check valves (4) to the low-pressure side of the system. Thus, it supplies makeup and cooling fluid to the system. This pump also provides fluid pressure for the pump control and inlet pressurization. This inlet pressurization is maintained by a low-pressure relief valve, which is one of the fluid controls (8) located on the motor. This valve relieves excess fluid from the charge pump through the low-pressure return line (10) and from the low-pressure side of the system. This excess fluid flows from the relief valve through the low-pressure return line (11), through the heat exchanger (13) and back to the reservoir, as indicated by the symbol (⊔).

A pilot-operated high-pressure relief valve, located in the fluid controls (8) on the motor, protects the system from oversurges or extremely high starting pressures. In order not to deplete the closed system of fluid, this high-pressure relief valve discharges excess fluid to the low-pressure side of the system.

A pressure-actuated shuttle valve, also part of the fluid controls (8) on the motor, directs high and low pressures to the respective relief valves. When one line is high pressure, the shuttle valve moves toward the low-pressure side. This action ports the high pressure to the high-pressure relief valve, which directs excess fluid from the high-pressure relief valve to the low-pressure side of the system. At the same time, the low-pressure side of the system is ported to the low-pressure relief valve.

The high-pressure line (12) is connected to the pressure side of the high-pressure relief valve. This line provides a passage for high-pressure fluid to flow to the transmission selector valve (15) and the pressure gage (14). The normal operating pressure will vary depending upon the load. Maximum allowable pressure is 4,500 psi.

The transmission selector valve (15) is a two-position valve, either OPEN or CLOSED. In the OPEN position, the transmission is in NEUTRAL and in the CLOSED position, the transmission is ENGAGED. The control for this valve is located on the control panel and is manually controlled by the operator. With the transmission in neutral and the valve open, fluid flows from the drive systems, through the high-pressure lines (12a and 12b), through the

alve (15), and back to the reservoir. Thereore, pressure cannot be built up in the drive ystems to rotate the motors. When the transnission is engaged, the valve is closed. This revents flow back to the reservoir and, thereore, allows pressure to build up in the drive ystems to operate the motors. The check alves (9a and 9b) prevent pressurized fluid rom either drive system from affecting the peration of the other drive system.

Fluid flow for the lifting linkage control sysem is provided by the constant displacement, ear type pump (16). Like the transmission ump, this pump is driven by the engine through he gearbox and receives its supply of fluid rom the same reservoir (1) through the filter 2). This pump delivers fluid to the system at he rate of approximately 9 gpm; however, this ate of flow varies with the speed of the pump.

Fluid from the pump flows through the reief valve (17). This valve protects the system rom pressures in excess of 2,400 psi by reieving excess fluid, which flows back to the eservoir. The system fluid then charges the ccumulator. The accumulator is precharged ith nitrogen to 1,000 psi. (Precharging acumulators is described later in this chapter nder the maintenance of weapons loaders.) 'he fluid flow from the pump charges the acumulator until the pressure reaches 2,400 si. The purpose and operation of this accumuator system are described later.

The fluid then flows to the flow divider (21). 'his valve divides the flow of fluid, allowing gpm to flow to the lift cylinder subsystem. his system is controlled with two solenoidperated two-way control valves.

The UP control valve (22) is normally open. hat is, when the solenoid is not energized, the egulated flow of fluid from the flow divider ows through the valve to the heat exchanger nd back to the reservoir. When the solenoid energized, the valve closes. Then, the reguted flow from the flow divider flows through e check valve in the DOWN control valve (23), rough the flow regulator (24) to the lift cylder (25). This forces the piston of the lift linder to move upward. Fluid from the other d of the lift cylinder flows to the low-pressure turn lines (10a and 10b) of the transmission stem. As explained previously, this fluid ows through the low-pressure relief valve, rough the heat exchanger, and back to the servoir.

The DOWN control valve (23) is normally closed. That is, when the solenoid is not energized and the UP control valve (22) is open to return, the check valve prevents fluid flow from the lift cylinder back into the system. This check valve is forced off its seat when the solenoid is energized. This allows fluid to flow from the lift cylinder, through the two control valves (22 and 23) to the heat exchanger. The low-pressure fluid provided by charge pumps (3a and 3b) through the low-pressure return lines (10a and 10b) and the weight of the lifting arms provide sufficient force to move the piston of the lift cylinder to the DOWN position.

The flow regulator (24) meters the flow from the lift cylinder, thus preventing the piston from moving too rapidly. The shutoff valve (26) is normally in the closed position. If the engine or the pump fails, the lift cylinder can be lowered by opening this valve. This allows fluid to flow from the lift cylinder through the shutoff valve and back to the reservoir.

There are two switches provided for each solenoid-operated control valve. One set of these switches is located on the control panel near the operator's seat and the other set is located on a control panel near the lift cylinder. The manual control for the shutoff valve (26) is also located near the lift cylinder.

The remainder of system fluid flows from the flow divider (21) to the second flow divider (27). This valve divides the flow of fluid, allowing 0.5 gpm to flow to the right-hand lifting arm IN and OUT subsystem.

The control valve for this system is a solenoid-operated, three-position, four-way, open-center valve. With neither solenoid energized, the valve is in neutral, allowing the regulated flow from the flow divider (27) to flow through the valve and back to the reservoir.

When one of the solenoids is energized, for example, the OUT solenoid, the sliding spool of the control valve moves to the right. This allows a passage for the fluid to flow through the control valve to the shuttle valve. This pressure forces the shuttle to the left, opening the passage from the control valve to the actuating cylinder (30). The pressurized fluid forces the piston to the right, extending the piston rod, which moves the lifting arm OUT. The return fluid from the rod side of the piston flows through the other passage of the control valve (28) to the reservoir.

When the IN solenoid is energized, the sliding spool of the control valve moves to the left.

In this position, the flow of fluid is reversed. The pressurized fluid from the system flows to the rod end of the actuating cylinder, and the return fluid flows from the opposite end of the cylinder, through the control valve, and to the reservoir. This retracts the piston rod, moving the lifting arm IN.

The remaining system fluid flows from the flow divider (27) to the third flow divider (31). This valve divides the flow, allowing 0.5 gpm to flow to the left-hand lifting arm IN and OUT subsystem. The operation of this subsystem is identical to that of the right-hand subsystem. All of the remaining fluid flows out of the other port of the flow divider (31) and to the reservoir.

In case the hydraulic pump fails, the lifting arms can be moved outward with accumulator pressure. The check valve (18) traps 2,400 psi in the accumulator. This pressurized fluid can be released to the lifting arm cylinders by opening the shutoff valve (20). This pressure repositions the shuttle valves (29 and 33), allowing the fluid to flow to the actuating cylinders (30 and 34). By energizing the OUT solenoids of the control valves (28 and 32), the fluid from the rod ends of both actuating cylinders flows through the corresponding control valves to the reservoir.

Switches for the solenoid-operated control valves are located on the operator's control panel and on control panels near the lift cylinder. The manual control for the shutoff valve (18) is located near the lift cylinder.

MAINTENANCE

Like all types of support equipment, the spotting dolly requires periodic inspections and servicing to insure safe and effective service. At the time of this writing, Maintenance Requirements Cards are not provided for this equipment. Therefore, the applicable Service and Repair Instructions should be consulted for the inspection intervals and procedures.

The fundamental troubleshooting procedures described previously can be adapted to this system. Since several of the control valves in this hydraulic system are solenoid-operated, subsystem failures may be traced to electrical trouble rather than hydraulic. A defective flow divider will affect the operation of the lift cylinder or the lifting arm IN and OUT cylinders. For example, assume that the second flow divider (item 26, fig. 14-9) fails to provide the entire 0.5 gpm to the right-hand lifting arm IN and OUT subsystem. This would result in sluggish operation of the actuating cylinder (30).

As stated in several places in this manual, all maintenance actions performed on support equipment are not considered complete until they have been recorded on the appropriate source document. Most maintenance actions are documented on the Maintenance Action Form (MAF) or the Support Action Form (SAF). Typical examples of these documents are illustrated elsewhere in this manual.

As explained in chapter 2, some models of support equipment may require modification at different times to improve the operation or safety characteristics. These modifications are issued in the form of Support Equipment Changes. When a change is incorporated in a specific item of equipment, the information is documented on the Technical Directive Compliance Form (TDCF). Figure 14-10 illustrates the documentation of Support Equipment Change No. 1791, which affects the control system of the SD-1D spotting dolly. Military Requirements for Petty Officer 3 & 2, NavPers 10056 (Series) and OpNav Instruction 4790.2 (Series) should be consulted for detailed instructions concerning the information required in each block.

Notice the terms SAMI and CAMI in Block B of the Work Center section (fig. 14-10). These are two of the three different types of Maintenance Instructions that are sometimes issued by the maintenance department. The third type is the TIMI. The purpose and use of these three types of Maintenance Instructions are discussed in the following paragraphs.

As discussed in chapter 2, some technical directives are issued in the form of messages. These messages are often so brief that they need considerable amplification and additional background information before they are thoroughly understandable. On the other hand, letter type directives which are quite lengthy and detailed may be received, especially if addressed to all aviation activities. Only parts of such directives may be applicable locally; therefore, the pertinent portions need to be selected and often condensed to adapt them to local conditions. Local maintenance departments use a standard form, Maintenance Instruction, OpNav 4790/35, for interpreting and/or amplifying these technical directives and other maintenance requirements received from higher authority. This form is also used to issue local technical instructions.

TECHNICAL DIRECTIVE COMPLIANCE FORM
OPNAV FORM 4790/43 (10-69) S/N 0107-770-4600

STATISTICAL DATA

1. JOB CONTROL NUMBER	2. TYPE EQUIP.	3. BU/SER NO.	4. ACTION ORG	5. WORK CENTER	6. MAINTENANCE LEVEL 1 ORG / 2 INT / 3 DEP	7. ACTION DATE
D99 1130 079	GPC2	000094	D99	920	[ ] ORG [X] INT [ ] DEP	1131

8. SYSTEM	9. STATUS	10. ITEMS PROC	11. MAN HRS	12. EMT	13. INTERIM	14. TECHNICAL DIRECTIVE IDENTIFICATION .1 CODE	.2 BASIC NO.	.3 REV.	.4 AMD	.5 PART	.6 KIT	15. CORR
15	C	1	3 2	3 2	[ ] YES [X] NO	62	1791				52	

46. OLD ITEM .1 MFGR	.2 SERIAL NUMBER	47. NEW ITEM .1 MFGR	.2 SERIAL NUMBER
.3 PART NUMBER		.3 PART NUMBER	

MAINT. CONTROL

A. PRI	B. PRIMARY WORK CENTER	C. ASSISTANT WORK CENTERS			D. BY DATE	E. EST M/H	F. CREW SIZE	G. KIT REQD.	H. SE REQD.
2	920	NONE			1131	3 0	1	[X] YES [ ] NO	[ ] YES [X] NO

I. REMARKS

MATERIAL

A. MATERIAL/KIT STOCK NUMBER	B. DATE ORDERED	C. STUB NO.	D. DATE RECEIVED	F. ISSUED BY
V62 1SEC 1791	1098	0896	1130	C.P. Conroy

E. REMARKS

G. DELIVERED BY: H. McMonaghan

H. DATE: 1131

WORK CENTER

A. STATUS	C. REMARKS	G-STATUS CODES
↑ (↓)		A-ASSISTING WORK CENTER
B. SAMI/CAMI NO. 16-71		C-COMPLIED WITH
		D-DOES NOT APPLY

D. ACCOMPLISHED BY	E. INSPECTED BY	F. SUPERVISOR	
E.L. Collom	P. Kimball	E. Brown	P-PREVIOUSLY COMPLIED WITH W-WORK IN PROGRESS

LOGS & RECORDS

A. COMPLIANCE RECORDED ON HISTORICAL RECORDS		B. DATE	SIGNATURE
[X] LOG	[ ] ACCESSORY CARD	1134	E. Ginther

C. CONFIGURATION FORM	DATE	SIGNATURE	D
[ ] YES [X] NO			

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Figure 14-10.—Technical Directive Compliance Form (TDCF) documentation.

The Maintenance Instruction is usually pre-ared by the cognizant division; however, it nay be drafted by any division designated by he Aircraft Maintenance Officer. A review of he draft should be conducted by the quality as-surance division as well as the maintenance/naterial coordinator before it is presented to he Aircraft Maintenance Officer for approval.

The three types of Maintenance Instructions ire the SAMI (Single Action Maintenance In-struction), CAMI (Continuing Action Mainte-ance Instruction), and TIMI (Technical Infor-nation Maintenance Instruction).

A SAMI is issued for the performance of work of a one-time nature. The work so or-dered is such that it will be completed on one model of equipment by carrying out the instruc-tions set forth, and will not require further ac-tion at any time or any situation on that model of equipment. An example of a SAMI is a Sup-port Equipment Change on all items of equip-ment of a certain model. When preparing this Maintenance Instruction, the box labeled Single Action at the top of the form is checked.

The SAMI itself is not authority to proceed with the work. It merely specifies what has to

be done and, when applicable, has appended to it all the necessary references, directives, and other information. Supporting source documents are initiated in conjunction with the SAMI for each item of equipment involved in order to establish the necessary control of the work.

Compliance with a SAMI is accomplished by maintenance control making an entry in their register, then relaying the job control number along with other pertinent facts (in code form) to the work center supervisor concerned. The work center supervisor makes necessary entries on his register and assigns personnel to comply with the SAMI. Verification of completion of the task along with the manhours expended are documented on the Maintenance Action Form.

In areas where technical directives are to be incorporated, compliance is accomplished by maintenance control issuing a TDCF. The TDCF illustrated in figure 14-10 is an example of this procedure. As shown, the TDCF initiates the maintenance action, verifies completion, and accounts for manhours expended.

Using a SAMI to describe the work and verbally initiating the action on each item of equipment simplifies source document preparation, standardizes record entries, and results in more orderly scheduling of the necessary work among all applicable items of equipment assigned.

When OpNav Form 4790/35 is used as a SAMI, the section on the back of the form is completed in order to provide a control for planning and record purposes. In this section are entered all the serial numbers of affected items of equipment. Upon completion of the required action on each listed number, the date is entered.

A CAMI, as its name implies, is a local directive providing instructions for the performance of work which is or may be of a continuing nature. Like the SAMI, it is not authority needed to proceed with the work. Here, too, a source document reports compliance with the directive. A CAMI is identified by a check in the Continuing Action box at the top of the OpNav Form 4790/35.

A CAMI is prepared and issued when a directive or situation dictates that specific work must be accomplished at recurring intervals which are contingent upon elapsed time or the occurrence of a particular condition or incident. It is important that each CAMI clearly state when the prescribed work is to be accomplished.

A supporting source document is required at the time of occurrence of the incident or the expiration of the time interval, as appropriate, to insure that the work is actually accomplished.

With the implementation of the Planned Maintenance System the need for CAMI's has been greatly reduced. If additional maintenance requirements of an inspection nature or recurring nature are received, they are added to the Maintenance Requirements Cards, rather than issued with a CAMI.

A TIMI is prepared and issued when a directive or situation requires that technical information be promulgated within an activity. When it is necessary to disseminate information, such as techniques and local policy, which does not direct the accomplishment of specific work at definite intervals, but which is sustaining in nature, a TIMI may properly be issued; for example, information concerning hydraulic fluid contamination. The OpNav Form 4790/35 is identified as being a TIMI when the Technical Information box at the top of the form is checked.

Whenever any Maintenance Instruction has served its purpose, it should be canceled. Cancellation is usually initiated by the maintenance control work center by forwarding a memorandum to each holder of copies of the Maintenance Instruction, such as the cognizant production division(s) and the quality assurance division.

WEAPONS LOADERS

Weapons loaders are illustrated and described briefly in chapter 4. As stated in chapter 4, the most modern types of weapons loaders (AERO 46 and AERO 47) depend upon hydraulic power to lift weapons, fuel tanks, JATO bottles, etc., and to maneuver these items into position for attachment to Navy military aircraft.

SYSTEM COMPONENTS AND OPERATION

The hydraulic systems of the different weapons loaders are very similar in design and operation. A representative system is illustrated in figure 14-11. Part (A) shows the location of the major hydraulic components within the vehicle; part (B) shows the location and interconnection of the components in the manipulator

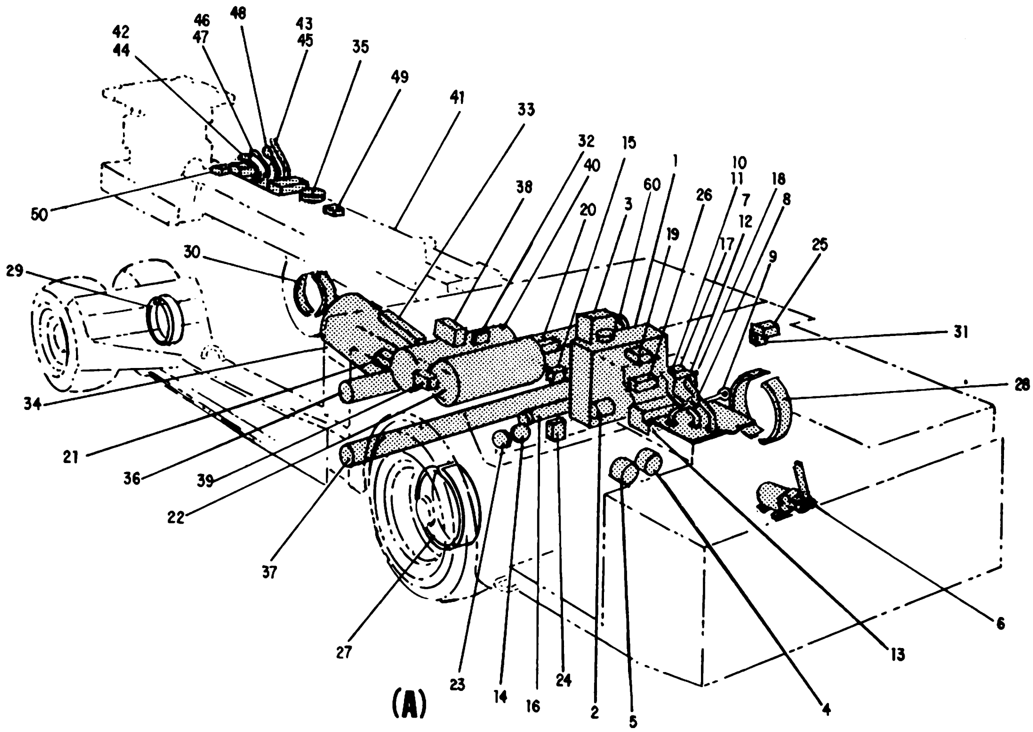

Figure 14-11.—Weapons loader hydraulic system. (A) Location of major components in vehicle.

ead; and part (C) is a schematic diagram of ie complete hydraulic system. Figure 14-12 lustrates a top view and a side view of the eapons loader. This illustration includes ome of the nomenclature of the loader, es- ecially those items which are actuated with ie hydraulic system.

The lifting mechanism consists of a boom, hydraulic cylinder, and a manipulator head ssembly. The lift boom is operated by a ouble-acting piston type hydraulic cylinder tem (34), fig. 14-11) which is mounted in the iidsection of the boom support. The manipu- tor head is located at the upper end of the lift oom at the forward end of the loader. The anipulator head supports the weapon or other em for loading either on four rollers or on an dapter on lifting forks.

The manipulator head and lift boom provide ix different motions—roll, tilt, yaw, longi- idinal, lateral, and lift motions. (In the fol- owing discussion, consider a weapon with its ongitudinal axis parallel to the axles of the ront wheels resting on the manipulator head in the position shown in figure 14-12.) A weapon supported on the manipulator head can be moved several degrees clockwise or counter- clockwise around its longitudinal axis (roll mo- tion). The weapon can be moved about its lateral axis; that is, nose up or nose down (tilt motion). It can be rotated about its vertical axis; that is, nose right or left (yaw motion). Lateral motion is provided by moving the boom in an arc to the right or left. This is referred to as azimuth. In addition to the lift motion provided by the lift boom, vertical motion is also provided by the manipulator head. All of these motions are accomplished through the use of hydraulic power.

As indicated in the foregoing, most of the different movements are provided by the ma- nipulator head. The hydraulic actuators which accomplish the movements provided by the ma- nipulator head are illustrated in figure 14-11 (B). The base frame of the manipulator head supports the yaw and ram (lift) mechanisms. A mount attaches the tilt and roll actuators to the yaw and ram mechanisms. A table (not shown

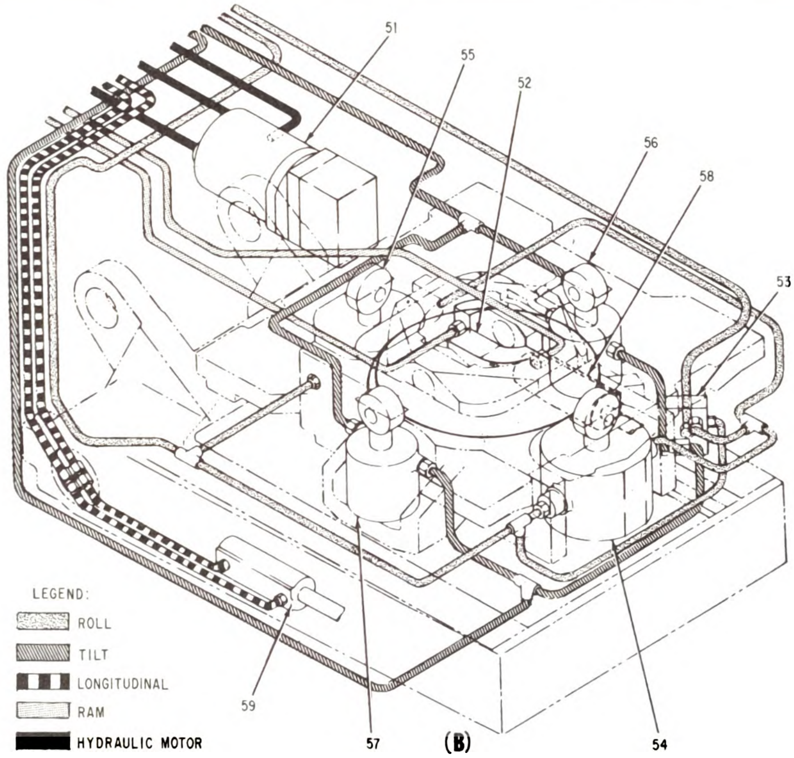

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Figure 14-11.—Weapons loader hydraulic system. (B) Interconnection of manipulator head components.

in figure 14-11) is the top plate of the manipulator head. It is attached to the yaw and ram mechanism by a universal type joint. The cylinder rods of the tilt and roll cylinders are attached to the table with straight pins.

Roll motion is accomplished by two counteracting hydraulic cylinders (items (54) and (55), fig. 14-11) mounted on the front and rear of the manipulator head. When actuated, the piston rod of one cylinder extends while the piston rod of the other cylinder retracts. This movement rolls the table several degrees up or down, thus rotating the weapon about its longitudinal axis.

Tilt motion is accomplished by two counteracting hydraulic cylinders (56 and 57) mounted on the left and right sides of the manipulator head. Like the roll cylinders, when actuated, one piston rod extends and the other retracts. This action imparts several degrees tilt in either direction.

Yaw motion is accomplished with a hydraulic motor (51). Through a drive gear mechanism, the motor rotates the table to approximately 95 degrees either side of center.

Lift motion is provided by a telescoping ram type actuating cylinder located in the center of the manipulator head. Actuation of this cylinder will provide approximately 15 inches of vertical movement of the table. (This lift movement is in addition to that provided by the boom lift cylinder.)

Longitudinal motion is accomplished by two hydraulic cylinders (58 and 59) mounted to the base frame and the yaw and ram mechanisms. By hydraulically extending or retracting the piston rods of these cylinders, the yaw and ram mechanism and, therefore, the table are moved fore or aft 2 inches.

Azimuth motion is accomplished by a double-acting hydraulic cylinder (40). This cylinder is not part of the manipulator head but is mounted to the frame of the vehicle and the boom. When actuated, the piston rod of the cylinder extends or retracts, forcing the boom and lift cylinder to revolve a maximum of 20 degrees to the left or right of center.

As indicated in figure 14-12, the side frames may be adjusted to various widths. This is also

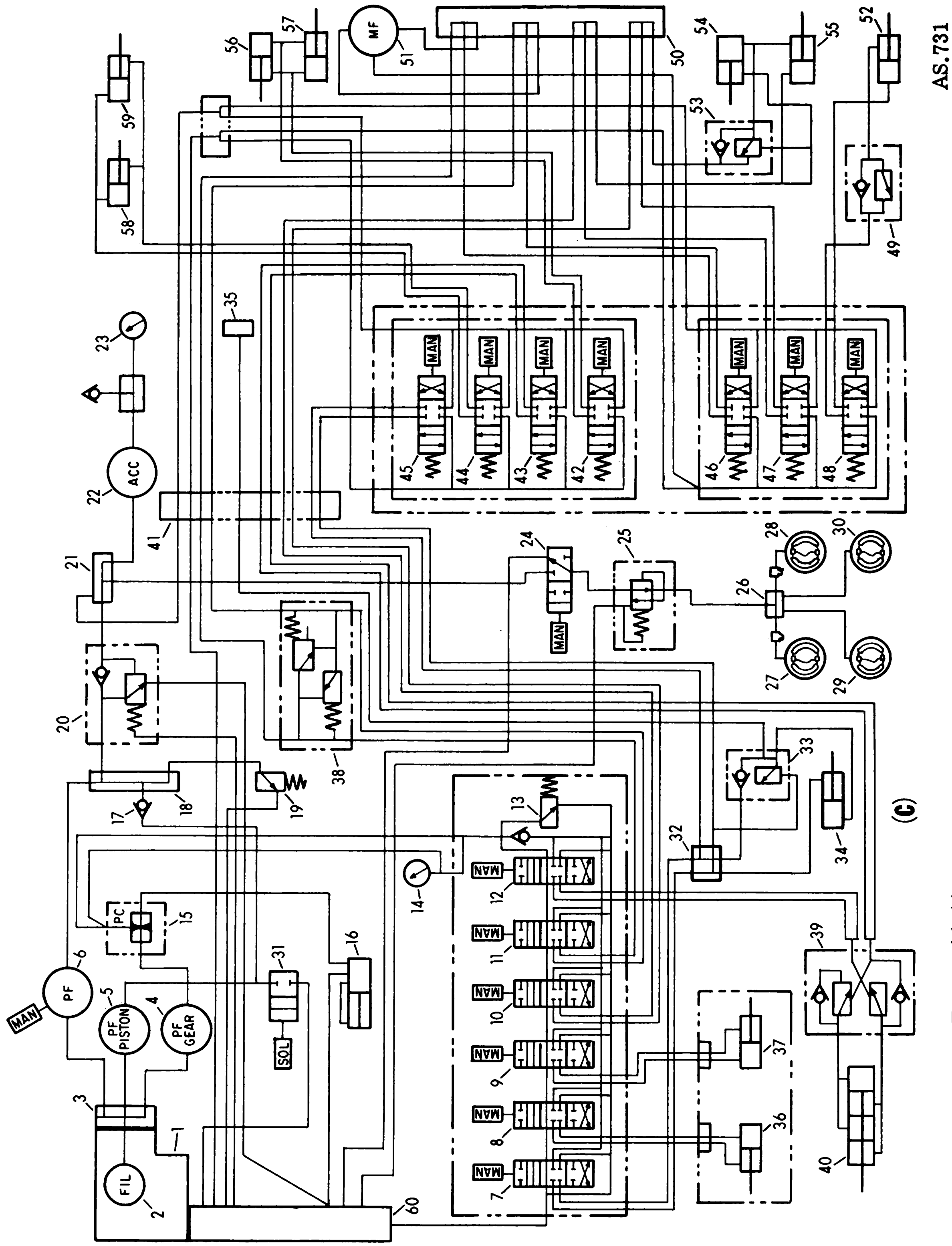


Figure 14-11.—Weapons loader hydraulic system. (C) Schematic diagram.

Nomenclature for figure 14-11, Parts (A), (B), and (C).

1. Hydraulic reservoir.
2. Filter.
3. Pump manifold.
4. Gear pump.
5. Piston pump.
6. Hand pump.
7. Main lift control valve.
8. Right side frame width control valve.
9. Left side frame width control valve.
10. Main roll control valve.
11. Main yaw control valve.
12. Main azimuth control valve.
13. Main pump relief.
14. System pressure gage.
15. Flow regulator.
16. Power steering cylinder.
17. Check valve.
18. Hydraulic manifold.
19. Relief valve.
20. Unloader valve.
21. Accumulator manifold.
22. Accumulator.
23. Accumulator pressure gage.
24. Power brake control valve.
25. Pressure reducer valve.
26. Brake manifold.
27. Left rear brake.
28. Right rear brake.
29. Left front brake.
30. Right front brake.
31. Solenoid valve.
32. Lift boom manifold.
33. Counterbalance valve.
34. Double-acting lift cylinder.
35. Pressure gage.
36. Right side frame width control. cylinder.
37. Left side frame width control cylinder.
38. Relief valve.
39. Double pilot check valve.
40. Azimuth cylinder.
41. Lift boom.
42. Tilt motion control valve.
43. Boom azimuth control valve.
44. Longitudinal motion control valve.
45. Boom lift control valve.
46. Boom yaw control valve.
47. Boom roll control valve.
48. Ram motion control valve.
49. Counterbalance valve.
50. Boom manifold.
51. Yaw motor.
52. Four sleeve telescoping ram.
53. Counterbalance valve.
54. Forward roll cylinder.
55. Rear roll cylinder.
56. Left tilt cylinder.
57. Right tilt cylinder.
58. Left longitudinal cylinder.
59. Right longitudinal cylinder.
60. Return manifold.

accomplished with hydraulic actuating cylinders (items 36 and 37, fig. 14-11).

NOTE: It is necessary to raise the front wheels off the ground with the lift boom before attempting to adjust the loader side frame widths.

The system (fig. 14-11) contains three hydraulic pumps. These pumps receive their supply of fluid through a manifold (3) from the same reservoir (1). The gear pump (4) is a constant displacement pump and is driven by the engine through a gearbox. This pump supplies a flow of fluid to the power steering system and to an open-center system similar to the forklift system described previously. A flow regulator (15) regulates the flow of fluid to the power steering cylinder (16) at the rate of 2 gpm. The remaining fluid flows through the relief valve (13) to the control valves. The relief valve protects the gear pump and system from pressures in excess of 1,500 psi.

This system contains six control valves. These control valves and the relief valve are combined into one assembly. The assembly is considered the main control valve and is located on the instrument panel on the right side of the steering wheel. Each valve is a four-way, three-position, spring-centered, sliding spool type, similar to the open-center valve described and illustrated in chapter 13. (See fig. 13-17.)

When all six valves are in the neutral position, the fluid flows through the assembly, through the return manifold (item 60, fig. 14-11), and back to the reservoir (1). When any one of the valves is actuated, the flow of fluid from the pump is directed to the corresponding actuator moving the actuated unit in the desired

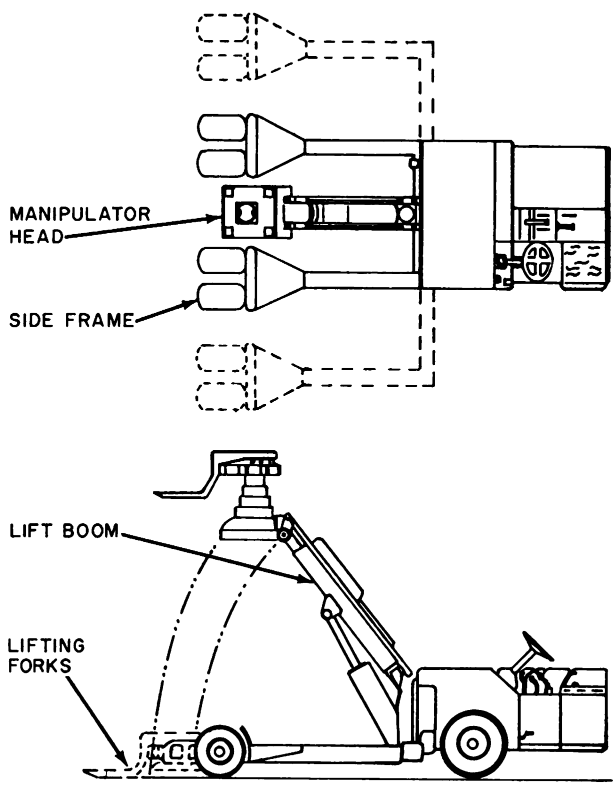


Figure 14-12.—Weapons loader—top and side views.

direction. The return fluid from the actuator flows back through the opposite ports of the actuated control valve to return. Two or more valves cannot be operated simultaneously. These six valves control the movements of the following actuators:

1. The main lift control valve (7) controls the actuation of the lift cylinder (34).
2. The side frame width control valves (8 and 9) control the actuation of the side frame width control cylinders (36 and 37).
3. The main roll control valve (10) controls the actuation of the two roll cylinders (54 and 55).
4. The main yaw control valve (11) controls the actuation of the yaw motor (51).
5. The main azimuth control valve (12) controls the actuation of the azimuth cylinder (40).

The flow of fluid to and from the roll cylinders and the yaw motor flows through a common manifold (50) located on the boom.

The piston pump (5) is also a constant displacement pump and is driven by the engine through the gearbox. This axial piston pump supplies a flow of fluid to a closed-center system.

In a closed-center system the control valves are arranged in parallel rather than in series. With the pump operating, the system is under pressure at all times. Therefore, some means must be provided to maintain system pressure in a closed-center system. A variable-displacement pump is used in some systems. As system pressure increases, the output of the variable-displacement pump decreases. When the system reaches normal operating pressure, the output of the pump decreases to zero.

An unloader valve, often referred to as a regulator, is used to maintain operating pressure in a closed-center system which contains a constant-displacement pump. The unloader valve may be in either of two positions—cut-in or cutout. With the unloader in the cut-in position, fluid flows from the pump into the system until normal operating pressure is reached. (Assume the normal operating pressure of a system is 1,500 psi.) When system pressure reaches 1,500 psi, the unloader valve is forced to the cutout position. In this position the system pressure is maintained; however, fluid from the pump continues to flow through the unloader valve back to the reservoir.

The unloader valve remains in the cutout position until system pressure decreases to a pressure somewhat below operating pressure. In a 1,500 psi system, the unloader is set to cut in at approximately 1,250 psi. The difference in cut-in and cutout pressures is known as differential or operating range. This range of pressure prevents the regulator from cutting in or cutting out with small changes in pressure.

The closed-center system illustrated in figure 14-11 is equipped with an unloader valve (20). The normal operating pressure of this system is 1,750 psi. The piston pump (5) provides a flow of fluid through the pressure manifold (18) to the power brake control valve (24) and to seven control valves. These control valves are combined into two assemblies. One assembly contains four valves and the other contains the remaining three. These valves are mounted on the boom and provide for precise positional control of the manipulator head. They may be operated by qualified personnel stationed near the weapon during loading operations.

Each valve is a four-way, three-position, closed-center, spring-centered, sliding spool type, similar to the closed-center valve described and illustrated in chapter 13. (See fig. 13-16.) These valves direct flow to and from their corresponding actuators in much the same manner as the open-center valves described previously. However, when in the neutral position, the closed-center valves do not allow a free flow of fluid through the valve from the pump to return. Fluid under pressure is directed to each valve. Therefore, each valve operates independently and can be actuated individually or in combination with any of the other valves. These seven valves control the movements of the following actuators:

1. The tilt motion control valve (42) controls the actuation of the two tilt cylinders (56 and 57).
2. The azimuth control valve (43) controls the actuation of the azimuth control cylinder (40).
3. The longitudinal motion control valve (44) controls the actuation of the longitudinal cylinders (58 and 59).
4. The boom lift control valve (45) controls the actuation of the lift cylinder (34).
5. The yaw control valve (46) controls the actuation of the yaw motor (51).
6. The roll control valve (47) controls the actuation of the two roll cylinders (54 and 55).
7. The ram motion control valve (48) controls the actuation of the telescoping ram (52).

Notice that the lift, yaw, roll, and azimuth actuators may be controlled either by open-center control valves located on the operator's panel or by closed-center valves located on the boom. For example, the lift boom may be lowered or raised by the actuation of either the main lift control valve (7) or the boom lift control valve (45). In either case, fluid flows from the actuated valve to the lift boom manifold (32). Here the fluid enters a common line to one end of the lift cylinder. The return fluid flows from the other end of the cylinder through the other line to the manifold. Remember, when either of these control valves is in the neutral position, the fluid passages to and from the actuator are blocked. Therefore, the fluid takes the path of least resistance and flows from the manifold through the actuated control valve to return. The boom manifold (50) serves the same purpose for the roll and yaw subsystems.

The four lines from the two azimuth control valves (12 and 43) join into two lines at the double check valve (39). This valve consists of two pilot-operated check valves which allow free flow to the actuator ports. The reverse flow from the actuator is blocked until pilot pressure from the pressure line to the actuator is sufficient to unseat the check valve and allow the return fluid to flow out of the actuator to return. This prevents movement of the boom unless adequate pressure is applied through the actuated control valve to the azimuth system. In case of hydraulic failure, this prevents the boom from swinging freely in both directions.

The closed-center system also contains a piston type accumulator (22). The accumulator is precharged on one side of the piston with nitrogen to 700 psi. (Precharging of the accumulator is described later under MAINTENANCE.) The pump then charges the accumulator with fluid until the pressure reaches 1,750 psi and the unloader cuts out. This supply of fluid serves to operate the system for a limited period in case of pump failure. The accumulator also serves to absorb shocks and to compensate for small leaks in the system.

A relief valve (19) is contained in the closed-center system. This valve protects the system from excessive pressures in the event that the unloader valve fails. The relief valve is set to relieve at 1,900 psi. If system pressure reaches 1,900 psi, the relief valve opens and returns the excess fluid through the return manifold (60) and to the reservoir (1).

The closed-center system is also equipped with a solenoid-operated bypass valve (31). This valve is connected in the system between the piston pump (5) and the hydraulic pressure manifold (18). It is electrically operated by a time delay relay in the ignition system. When the ignition system is turned on, the time delay relay opens the bypass solenoid valve for 5 seconds, allowing the fluid pumped by the piston pump to flow through and return to the reservoir. This relieves the strain that would be put on the engine and starter if hydraulic fluid was being pumped under pressure into the accumulator and system before the engine starts.

A hand pump (6) is provided in the weapons loader system. This pump is connected to the closed-center system. It can be used to operate any part of the hydraulic system except the side frame adjustment cylinders. This pump is used in the event of engine or pump failure. It can also be used to conduct operational checks on various parts of the system. A check valve (17) prevents the flow of fluid

n the hand pump from entering the piston ıp.

The weapons loader system also contains ıterbalance valves. The counterbalance 'e (33) in the lift cylinder prevents collapse ıe lift boom in the event of hydraulic failure ine breakage. The valve is located on the cylinder and is connected in the up line. s valve requires 250 psi to lower the load. dequate pressure is not available, the load ıot be lowered, thus preventing collapse of load due to any malfunction. Similar ıterbalance valves (49 and 53) are provided ıe ram and roll circuits.

'our relief valves are provided in the hy- ılic system to protect the components from essive pressures. Two of these valves (13 19) were described previously. A dual re- valve (38) located in the yaw system pro- s the yaw motor from pressures in excess ,000 psi. An internal relief valve (not shown gure 14-11) is built into the power steering nder (16) to prevent pressures of more than)0 psi from being developed in the cylinder.

The pressure reducing valve (25) limits the ssure from the brake control valve (24) to wheel brakes. In other words, it reduces 1,750 psi system pressure to 450 psi, the ssure required to operate the brakes.

There are three pressure gages in the sys- . Two of these gages indicate standard ssure and are located on the lower left side the instrument panel. One of these two es is the main system pressure gage (14). s gage indicates pressure in the open-center tem. The other standard gage (23) indi- es accumulator (closed-center system) ssure. The third gage is a force indicator e. It is mounted on the boom behind the m-mounted controls. It is calibrated to ister the weight of a weapon or other item he manipulator head when the system is at t. It does not give a true indication of the ght of the weapon while being lifted.

INTENANCE

Like the maintenance of all ground support ipment, the maintenance of weapons loaders uires the use of applicable Instructions ıuals and Maintenance Requirements Cards. ntenance procedures are similar to those ed for the forklift system. One additional n which requires particular attention is charging the accumulator.

To check the accumulator precharge pressure, deplete the hydraulic system pressure by actuating one of the subsystems. With system pressure depleted the pressure gage should read 700 psi, the correct precharge pressure. If this pressure is less than 700 psi, the accumulator must be precharged.

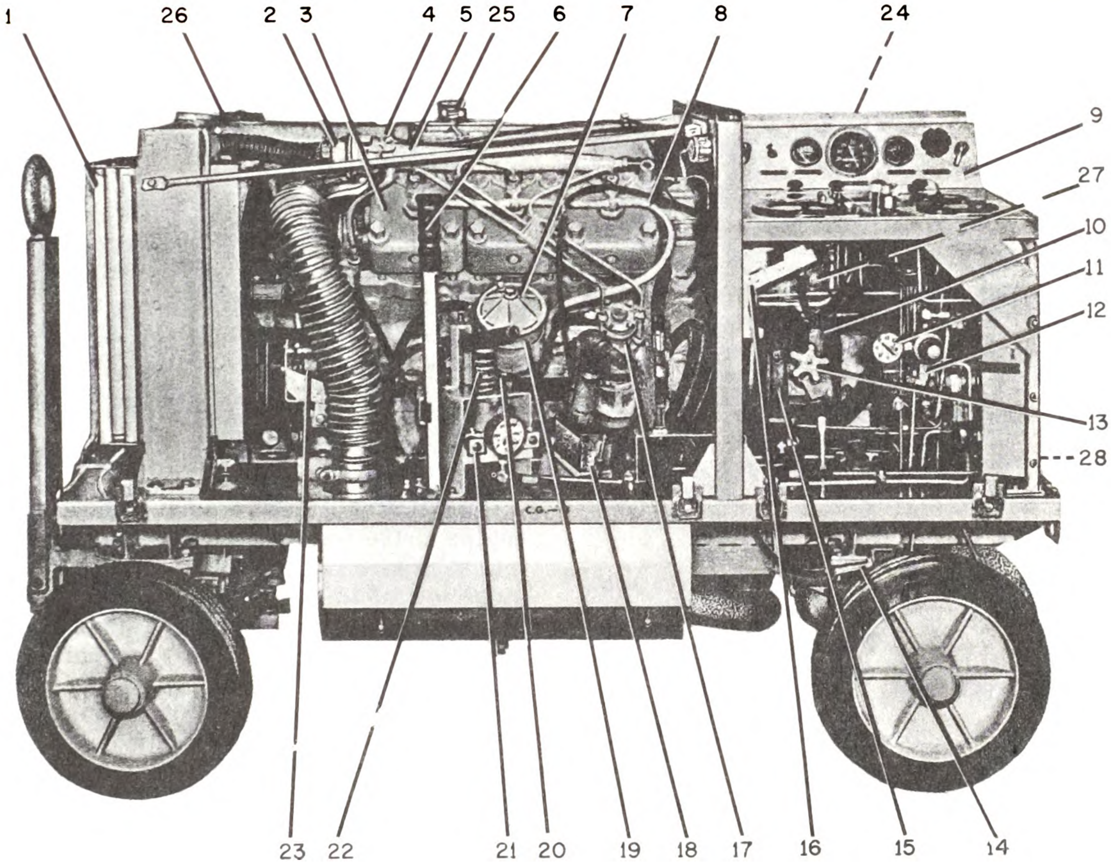
The accumulator precharge valve is located on a tee fitting on the gas end of the accumulator. The other line from the tee is connected to the accumulator pressure gage. To precharge the accumulator, remove the valve cap from the valve and charge the accumulator to a pressure of 700 psi. Only nitrogen should be used to charge the accumulator. After charging the accumulator to the proper pressure, replace the valve cap and tighten it securely.

Troubleshooting procedures similar to those for the forklift hydraulic system can be used to determine the cause of malfunctions in the open-center system of the weapons loader hydraulic system. The action of the unloader valve can be used to determine and locate internal leaks in the closed-center system. For example, assume there is an internal leak in the ram cylinder (52). When this system is selected with the control valve, the leakage of fluid from the pressure side of the piston to the return side causes system pressure to decrease. This decrease in pressure causes the unloader valve to cut in. However, the pressure immediately builds up and the unloader valve cuts out. The system pressure continues to fluctuate, causing the unloader valve to rapidly cut in and cut out. This is referred to as "chatter" and can easily be heard when the system is operating.

The cause of malfunctions in those subsystems which have dual control valves may sometimes be determined by checking the operation with each control valve. For example, if the lift cylinder (34) fails to operate when using the open-center control valve, first, attempt to actuate the other subsystems with the corresponding open-center control valves. If the other systems operate normally, attempt to actuate the lift cylinder with the corresponding closed-center control valve. If the lift cylinder still fails to actuate, the probable cause of the malfunction is isolated to the lift subsystem.

HYDRAULIC TEST EQUIPMENT

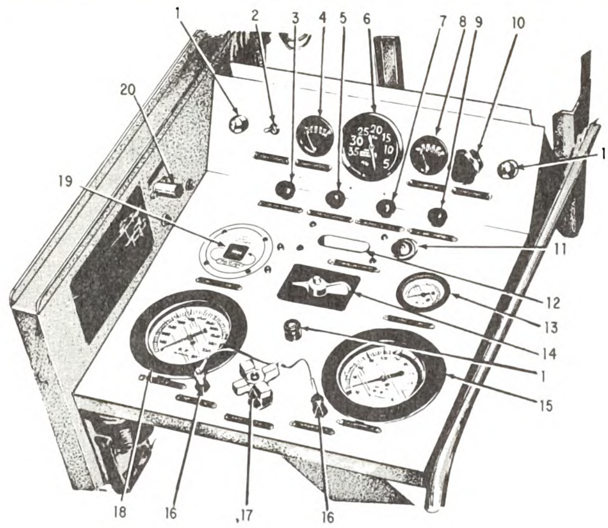
There are two general classes of hydraulic test equipment—the portable test stand and the



1. Oil cooler (hydraulic).
2. Thermostat housing.
3. Diesel engine.
4. Vent.
5. Water manifold.
6. Hand pump handle.
7. Filter cover, fuel.
8. Fuel return line.
9. Main control panel.
10. Compensator.
11. Bottle gage, nitrogen supply.
12. Nitrogen regulators.
13. Volume control.
14. Brake cable.
15. High-pressure pump.
16. Ether start aid.
17. Fuel injection pump.
18. Hand pump.
19. Fuel filter.
20. Drain plug.
21. Starting and fuel valve assembly (low boost cutout).
22. Start valve.
23. Charging pump.
24. Differential pressure switches (located behind main control panel).
25. Hydraulic reservoir.
26. Fuel tank.
27. Thermoswitch.
28. Secondary control panel (located on rear of test stand).

Figure 14-13.—Model AHT-64 test stand (housing removed).

hydraulic component test bench. In addition to these, the flexible hose check stand, described in chapter 12, is sometimes classified as hydraulic test equipment. Portable test stands and component test benches are discussed in the following sections.



AM.862

1. Panel lights.
2. OFF-ON panel light switch.
3. High-pressure filter indicator.
4. Engine oil pressure gage.
5. Pump case filter, high differential pressure.
6. Tachometer-hourmeter.
7. Low-pressure filter indicator.
8. Head temperature gage.
9. Fluid temperature warning light.
10. Throttle.
11. Filter bleed pushbutton.
12. Filter bleed sight tube.
13. Fluid temperature gage.
14. Pressure selector valve.
15. Compound gage.
16. Gage test fittings.
17. Pressure bypass valve.
18. High-pressure gage.
19. Fluid flow indicator.
20. Ether start button.

Figure 14-14.—Model AHT-64 test stand—main control panel and instruments.

PORTABLE TEST STANDS

In most aircraft the hydraulic pump is driven by the aircraft engine. Portable test stands, often referred to as hydraulic jennies, provide a means of simulating the engine-driven hydraulic pump. In other words, by connecting a test stand to the aircraft's hydraulic system, the various actuating systems may be cycled without turning up the aircraft. The test stand is connected to the aircraft system at ground test couplings (quick disconnects) provided on the aircraft.

As stated in chapter 4, portable test stands may be electric-motor driven, gasoline-engine driven, diesel-engine driven, or air driven. The electric-motor, gasoline-engine, and diesel-engine driven are the most widely used. Some of the most common portable test stands are described in the following paragraphs.

Model AHT-64 Test Stand

The model AHT-64 test stand is a diesel-engine driven unit, manufactured by Sun Electric Corporation. Figure 14-13 illustrates a side view of the complete unit, figure 14-14 illustrates the main control panel and instruments, and figure 14-15 the secondary control panel and instruments.

The test stand is designed to quickly and accurately check the performance and operating characteristics of hydraulic systems installed in aircraft. As a portable, completely self-contained unit, it will perform the following functional tests and operations:

1. Provide a source of hydraulic fluid at controlled pressures to operate the hydraulic components without the necessity of starting the aircraft engine.

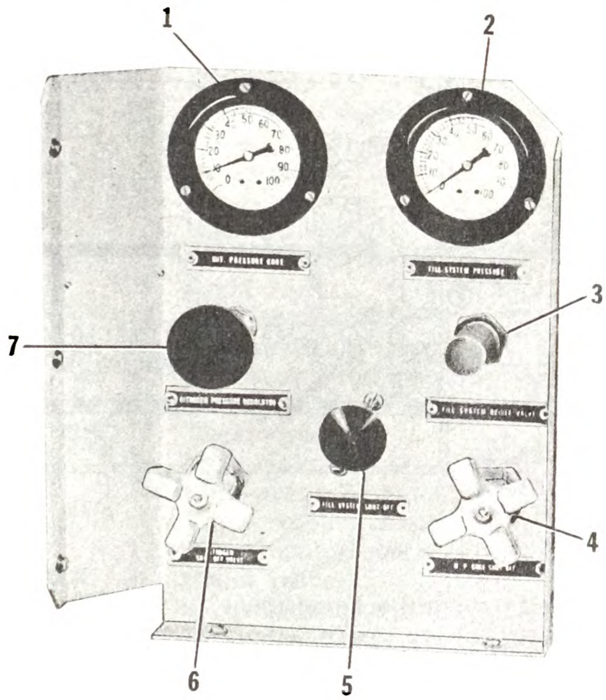
2. Test the aircraft hydraulic system for evidence of component malfunction, and flow or pressure leakage.

3. Drain, flush, and refill the aircraft hydraulic systems with micronically filtered hydraulic fluid.

4. Provide a source of hydraulic power for static proof pressure testing of aircraft systems and components at pressures up to 5,000 psi.

5. Provide a source of nitrogen for servicing aircraft at pressures of 0 to 100 psi.

The test stand is capable of operating under ambient temperatures ranging from -20° to 125° at a relative humidity of 0 to 100 percent. The unit is designed to deliver a fluid volume of 20 to 24 gpm at a pressure of 3,000 psi and 10 to 13 gpm at 5,000 psi. Fluid contamination during the test cycle is constantly controlled by 3- and 10-micron, replaceable element filters.



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1. Nitrogen pressure gage.
2. Fill system pressure gage.
3. Fill system relief valve.
4. High-pressure gage shutoff.
5. Fill system shutoff valve.
6. Nitrogen shutoff valve.
7. Nitrogen pressure regulator.

Figure 14-15.—Model AHT-64 test stand—secondary control panel and instruments.

The model AHT-64 test stand is of welded construction and mounted on four solid rubber tired wheels. It has a tow bar to facilitate steering by hand or with a tractor and a mechanical hand brake system which acts on the rear wheels. The components of the test stand are enclosed in a removable, two-section, weather resistant steel housing equipped with weather stripped hinged doors to permit access to the interior for inspection, ventilation, servicing, and maintenance. The external hoses are stowed on the rear of the test stand and are connected to the rear of the test stand and the aircraft hydraulic system by the use of quick-disconnects.

The power source for this test stand is a 3-cylinder, 2-cycle diesel engine. It is equipped with a pushbutton ether start system which sprays ether into the engine air intake manifold for cold starting. As a safety feature, a temperature sensing device attached to the engine water manifold automatically prevents pushbutton operation of the ether system when the engine is warm. The engine is capable of operating on DF-1 and DF-2 diesel fuels. It has an oil filter, fuel line filter, and other necessary accessories.

The engine is provided with a throttle, ether start button, start valve, oil pressure gage, cylinder head temperature gage, tachometer, and other necessary accessories. The main hydraulic system and engine controls are located on the control and instrument panel and are identified by applicable nameplates. (See fig. 14-14.) The secondary control panel contains the auxiliary controls and the nitrogen and fill system gages and are also identified by applicable nameplates. (See fig. 14-15.)

The hydraulic pump unit, comprising a boost pump and a high-pressure pump is directly coupled to the engine. A splined, shear coupling between the engine and the hydraulic pump unit prevents damage to the pump. The boost pump is an internal gear of the Gerotor type. It supplies a boosted hydraulic flow and pressure to the suction side of the high-pressure pump thereby assuring adequate flow to the high-pressure pump under maximum flow conditions. The high-pressure pump is a variable-volume, pressure-compensated, axial-piston type pump.

The hydraulic test system of the AHT-64 consists of two segments—the fill system and the high-pressure system. The fill system serves the purpose of originally filling the aircraft system with fluid from the test stand reservoir, and replenishing the aircraft system with fluid which may be lost during bleeding operations. The high-pressure system furnishes fluid under controlled conditions of flow and pressure to the aircraft system for the performance of testing operations. The basic operating principles of the test stand are explained in the following paragraphs. References are made to figure 14-16, which illustrates the system schematic of the test stands.

Fluid to fill and bleed the test stand system is initially taken from the test stand reservoir (1) when the reservoir selector valve (5) is in TEST STAND RESERVOIR position. This

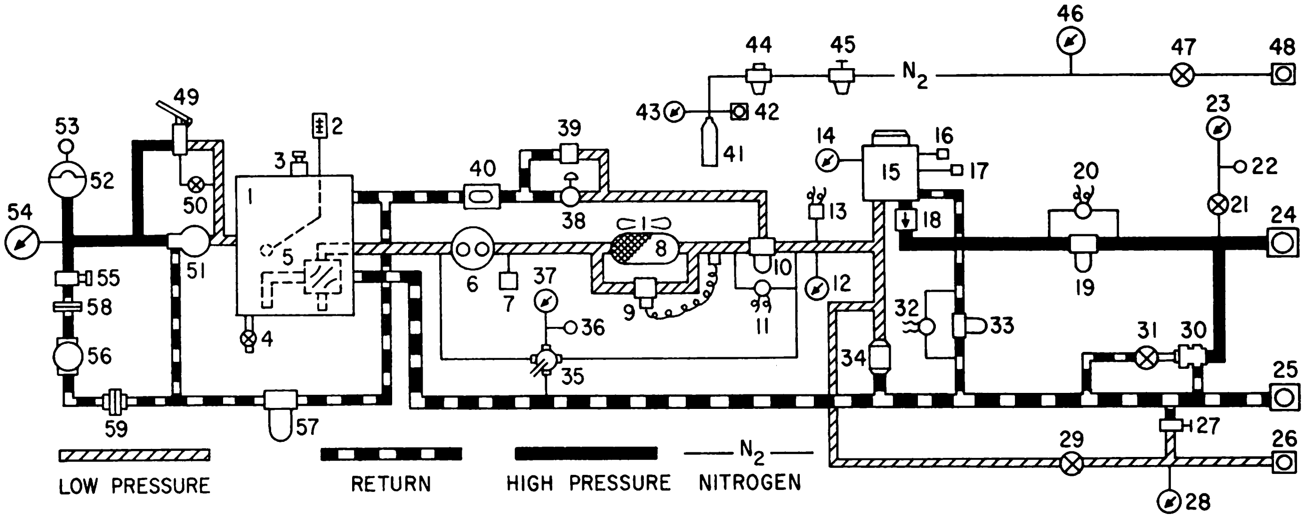

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Figure 14-16.—Model AHT-64 hydraulic system schematic.

provides fluid to the boost pump (6). The boost pump delivers the fluid at 120 psi through the fluid cooler (8) (or the bypass) and through a 10-micron, low-pressure filter (10) to the inlet port of the high-pressure pump (15). A thermal switch (13) at the inlet to the high-pressure pump is actuated when the temperature of the fluid exceeds 160° F. The temperature controller (9) routes the fluid through the fluid cooler or the bypass, depending upon the fluid temperature. The low-pressure filter (10) has a differential pressure switch (11) installed across it to illuminate an indicator on the control panel should the differential pressure across the filter become excessive. An air bleed circuit with relief valve bypass is connected from the filter (10) back to the reservoir. The sight tube (40) and pushbutton (38) provide a means for bleeding entrapped air from the filter. An inline relief valve (39) relieves abnormal pressures which may build up in the low-pressure filter and low-pressure system when the test stand is subjected to high ambient temperatures while stored. At the inlet to the high-pressure pump (15) is a pressure relief circuit through the inline relief valve (34) to the return line.

The high-pressure pump (15) delivers the fluid through the check valve (18) and high-pressure 3-micron filter (19) to the pressure disconnect port (24). The high-pressure relief valve (30) is manually adjusted to 10 percent above the pressure compensator setting to protect the hydraulic components from overpressure. The relief valve bypasses flow to the return line when actuated by system pressure or by the manually controlled pressure bypass valve (31).

Fluid is returned from the aircraft system through the return port (25) to the reservoir selector valve (5) which either connects the reservoir into the system, making reservoir fluid available, or bypasses the reservoir thereby taking fluid out of the system. Return line fluid pressure may be read on the compound gage (37) when it is connected to the return line through the gage selector valve (35).

The fill system components consist of the outlet port (26), pressure gage (28), relief valve (27), and pushbutton shutoff valve (29). Hydraulic fluid from the low-pressure filter (10) flows through the shutoff valve (29) to the outlet port (26). The pressure of the fill system is regulated by the manual setting of the relief valve (27), the outlet pressure being indicated on the fill system pressure gage (28).

As stated previously, the AHT-64 provides a source of nitrogen for servicing aircraft at pressures of 0 to 100 psi. A schematic of the nitrogen system is included in figure 14-16. Refer to figures 14-13 and 14-15 for the location of the components and controls.

Referring to figure 14-16, the nitrogen supply is stored in the bottle (41) under 1,800 psi

Nomenclature for figure 14-16.

1. Reservoir.
2. Fluid level gage.
3. Reservoir fill and vent.
4. Drain valve.
5. Selector valve.
6. Boost pump.
7. Low boost shutdown.
8. Fluid cooler.
9. Fluid temperature controller.
10. Low-pressure filter.
11. Pressure differential switch.
12. Fluid temperature gage.
13. Thermoswitch.
14. Flow indicator.
15. High-pressure pump.
16. Pump volume control.
17. Compensator control.
18. Check valve.
19. High-pressure filter.
20. Pressure differential switch.
21. Gage shutoff valve.
22. Gage test connection.
23. High-pressure gage.
24. High-pressure disconnect.
25. Return disconnect.
26. Fill system disconnect.
27. Fill system relief valve.
28. Fill system pressure gage.
29. Fill system shutoff.
30. High-pressure relief valve.
31. High-pressure bypass.
32. Pressure differential switch.
33. Pump case filter.
34. Low-pressure relief valve.
35. Gage selector valve.
36. Gage test connection.
37. Compound pressure gage.
38. Pushbutton bleed valve.
39. Thermal relief valve.
40. Sight tube.
41. Nitrogen bottle.
42. Nitrogen charging valve.
43. Nitrogen bottle pressure gage.
44. High-pressure nitrogen regulator.
45. Low-pressure nitrogen regulator.
46. Nitrogen pressure gage.
47. Nitrogen shutoff.
48. Nitrogen supply connection.
49. Hand pump.
50. Pressure bypass.
51. Accumulator charging pump.
52. Accumulator.
53. Accumulator precharge valve.
54. Accumulator pressure gage.
55. Hydraulic starting valve.
56. Hydraulic starting motor.
57. Starting system filter.
58. Buddy start pressure disconnect.
59. Buddy start return disconnect.

pressure. The system can be replenished by adding nitrogen through the charging valve (42) and checked by reading the primary pressure gage (43). Nitrogen gas pressure reduction from 1,800 psi to a using range of 0 to 100 psi is accomplished in two stages. The first stage regulator (44), which is located under the instrument panel, reduces the pressure from 1,800 to 100 psi. This regulator has a fixed pressure setting and should not be changed. The second stage regulator (45), mounted on the secondary control panel, controls the desired output pressure. This regulator is adjusted to the desired pressure for servicing. This pressure is indicated on the pressure gage (46). The nitrogen is supplied to the servicing point through the connection (48) by opening the shutoff valve (47).

Only qualified personnel, normally of the AMH rating, should use hydraulic test stands for checking aircraft systems. However, since the ASH is responsible for the maintenance of these test stands, he must be thoroughly familiar with its operation.

Before placing the test stand in operation, the operating personnel should thoroughly familiarize themselves with the nature, location, and function of all switches, controls, and instrumentation on the test stand control panels as well as other locations on the unit. No attempt should be made to operate the test stand to apply loads until the operator understands the layout and function of the control components.

Before attempting to operate the test stand, the following procedures should be performed.

1. Make certain the test stand is suitably located where adequate operating room, ventilation, and dissipation of engine heat are available.
2. Set parking brakes securely.
3. Open all necessary access doors.

4. Check that the hydraulic fluid level in the test stand reservoir is approximately 3/4 full as indicated on the gage (item 2, fig. 14-15).

CAUTION: If required, replenish reservoir to 3/4 full only. A partially empty reservoir allows for a 2-gallon discharge from a charged accumulator. Do not puncture the screen in the reservoir fill neck during filling operation.

5. Check the fuel gage, radiator level in cooling system, lubricating oil level at dipstick, and oil reservoir of the air cleaner. Replenish if required.

NOTE: Do not allow the engine fuel tank to become empty. Starting the engine after refilling an empty tank will require priming the fuel system.

6. See that the nitrogen bottle pressure gage reads 500 to 1,800 psi. Recharge if necessary.

7. Check the hydraulic accumulator pressure gage. The gage should register a minimum of 2,000 psi for starting the test stand. Use the hand pump to charge the accumulator to the required pressure.

8. Check that the pointers of all other pressure gages rest at near zero.

9. Connect ends of the pressure, return, and fill system external hoses to the hose storage manifold.

The diesel engine of the test stand should be started as follows:

1. Open the high-pressure shutoff valve located on the hose storage manifold.

2. Check accumulator pressure gage. Use the hand pump to increase pressure up to 2,000 psi, if necessary.

3. Pull throttle out approximately 1 1/2 inches.

NOTE: Be sure the arm on the fuel injection pump (located on the pump side opposite the throttle arm) is in UP position for full fuel flow. For emergency purposes, this arm can be pushed down to stop the engine.

4. For cold starting only, depress the ether start button a full stroke while counting five, then release. If the engine falters after starting, ether start button can be depressed again a partial stroke.

CAUTION: Do not attempt to use the ether start after the engine has reached operating temperature.

5. Crank engine by depressing the starting valve handle with a firm steady stroke until sound of meshing gears is heard. Immediately depress the valve handle remainder of stroke. Hold the handle down until the engine fires; then release.

6. After the engine starts, adjust the throttle for engine speed of 1,000 rpm as shown on tachometer and allow the engine to warm up for 2 or 3 minutes before proceeding with test.

NOTE: A "Buddy" starting system is provided on the AHT-64. This system may be used to start the engine of the test stand and may also be used to start another test stand which is equipped with a "Buddy" starting system. The applicable technical manual should be consulted for the procedures involved in this method of starting the test stands.

Prior to connecting the test stand to an aircraft, the test stand hydraulic system must be flushed with system fluid and bled of any entrapped air. To accomplish this, the following steps must be performed with the loose ends of the external hoses connected to the hose storage manifold. In this manner, the hoses form a closed loop.

NOTE: As an aid to better understand the operation of the hydraulic system of the test stand, all reference numbers in the remaining procedures concerning the operation of the AHT-64 correspond to the numbers on the system schematic illustrated in figure 14-16. The location of most of these components, controls, and instruments may be found in figures 14-13, 14-14, and 14-15.

1. Set the throttle for engine speed 2,400 rpm.

2. Let the test stand run to flush and bleed the hoses.

3. Press the fill system shutoff pushbutton (29) to flush fill system hose.

4. Slowly close the pressure bypass valve (31).

5. Adjust the pump volume control handwheel (16) for the flushing flow desired as indicated on the fluid flow indicator (14). Tighten lock handle behind handwheel or the volume control setting may change.

6. Depress the filter bleed pushbutton (38) until no air bubbles appear in the sight tube (40).

7. Flush hoses for approximately 3 minutes.

The pressure compensator and high-pressure relief valve are adjusted in the following manner.

1. Close the high-pressure shutoff valve located on the hose storage manifold, then slowly close the high-pressure bypass valve (31).

2. Loosen the knob locknut and turn the adjusting knob of the high-pressure relief valve (30) counterclockwise until the high-pressure gage (23) needle varies with knob movement. This indicates the high-pressure relief valve setting. Adjust the high-pressure gage shutoff valve (21) until the pointer of the gage stops pulsating and gives a steady reading.

3. Turn the pump compensator control knob (17) clockwise one or two turns.

4. Turn the adjusting knob of the high-pressure relief valve clockwise until the high-pressure gage reads 200 to 300 psi above the desired compensator setting. Secure the knob locknut.

5. Turn the pump compensator control (17) counterclockwise until the high-pressure gage (23) indicates the desired pressure setting. Pump compensation can be detected by the change in sound and the movement of fluid flow indicator (14) toward zero flow. Secure the locknut.

6. Slowly open and close the pressure bypass valve (31) to check compensator action and pressure compensator setting. Adjust further if necessary.

The fill system pressure must be adjusted to prevent excessive pressure from being applied to the aircraft reservoir. The fill system relief valve is adjusted as follows:

1. Loosen the locking nut and turn the knob of the fill system relief valve (27) counterclockwise to reduce pressure setting.

2. Disconnect end of fill system outlet hose at outlet port.

3. Press pushbutton of the fill system shutoff valve (29) and observe pressure reading on the fill system pressure gage (28). While pressing the fill system shutoff valve button, turn the knob of the fill system relief valve (30) for desired pressure on gage.

4. Lock the knob of the fill system relief valve.

5. Connect the fill system outlet hose to the outlet port.

After the test stand hydraulic system has been filled with the correct hydraulic fluid, bled of air, and appropriate pressures have been adjusted, the unit is ready for connection to the aircraft. The applicable technical manuals for both the test stand and the specific aircraft should be consulted for the correct operating and testing procedures.

Upon completion of the required tests, the test stand is shut down as follows:

1. Slowly open the pressure bypass valve (31).

2. If the hydraulic fluid is hot and it is desired to lower the temperature prior to shutdown, then allow the fluid to circulate with the pressure bypass valve open until the temperature gage (12) reading decreases to the desired value.

3. Let the engine run at 1,000 rpm for about 5 minutes.

4. Push throttle down completely.

5. Place panel light switch in OFF position.

6. Remove external hoses from aircraft hose ports and connect loose ends to the hose storage manifold of the stand.

7. Close all access doors to protect instruments and controls.

Model AHT-63 Test Stand

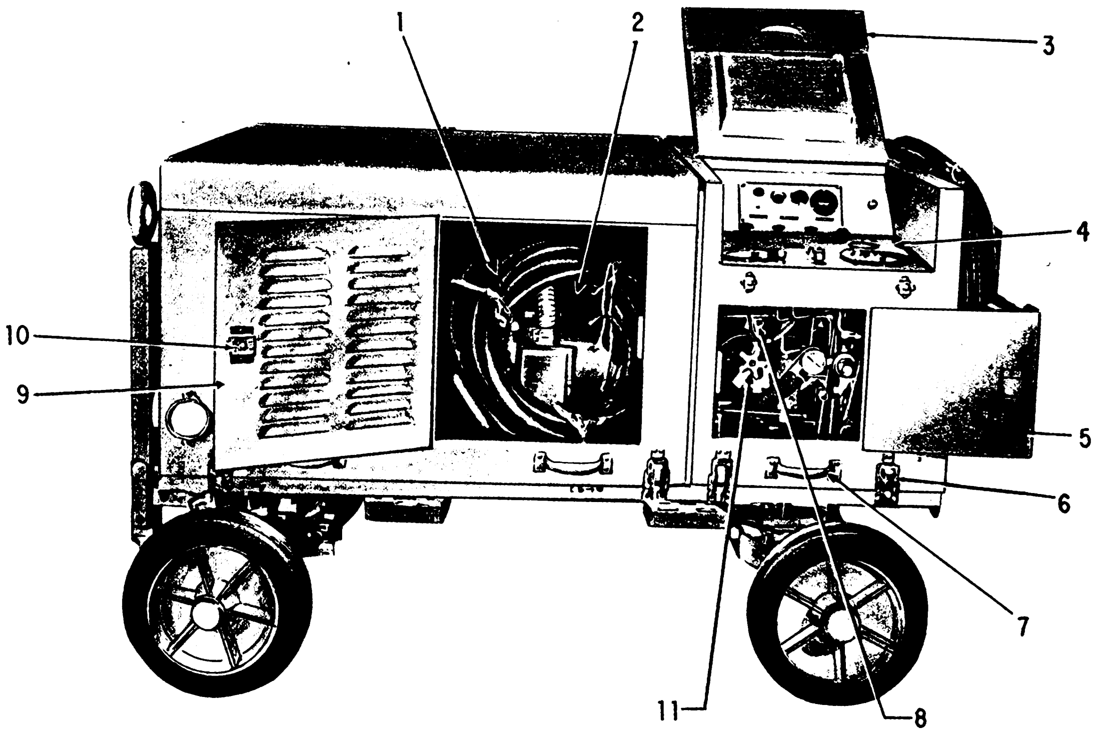
The AHT-63 test stand is also manufactured by Sun Electric Corporation. This test stand is identical to the AHT-64, described previously, except that the model AHT-63 is powered by an electric motor. As a comparison to the AHT-64 illustrated in figure 14-13, a side view of the AHT-63 test stand is shown in figure 14-17.

The electric motor is a 50-hp, 3,520 rpm, drip proof type, and is capable of operating on 220/440-volt, 3-phase, 60-Hz (cycle) current. The motor is a double end shaft type, one end for driving the high-pressure pump and the other end to drive the fluid cooler fan. The motor is equipped with a magnetic starter, a thermal overload relay for protection, a reverse phase relay to protect the pump unit from reverse rotation caused by incorrect electrical power phasing, and a low-pressure switch to stop the motor when boost pressure is too low at the high-pressure pump inlet. Fifty feet of neoprene covered, 3-phase electric cable with ground wire suitable for operation on either 220- or 440-volt current is provided. The control circuit is further protected by a circuit breaker and fuses.

The principles of operation and the operating procedures for the model AHT-63 test stand are basically the same as those for the model AHT-64 and, therefore, are not covered in this manual.

Model XMA-75 (Sun)

The model XMA-75 hydraulic test stand is also manufactured by the Sun Electric Corporation. This test stand is designed for shore or



1. Electric input cable.
2. Electric drive motor.
3. Control panel access door.
4. Control panel.
5. Compensator control and nitrogen gage access door.
6. Positive lock fastener.
7. Housing lifting handle.
8. Compensator control.
9. Electrical connection access door.
10. Latch.
11. Pump volume control.

Figure 14-17.—Model AHT-63 hydraulic test stand, left side.

shipboard use to quickly and accurately check the performance and operating characteristics of aircraft-installed hydraulic systems.

Like the test stands discussed previously, this test stand provides a source of hydraulic fluid under pressure to operate aircraft hydraulic components.

In addition, it tests the hydraulic system for evidence of component malfunction and flow or pressure leakage. It is also designed to drain, flush, and refill the aircraft hydraulic system with micronic-filtered hydraulic fluid conforming to Military Specification MIL-H-5606.

The XMA-75 test stand, shown in figure 14-18, consists basically of a completely self-contained hydraulic pumping system, mounted on a four-wheel trailer to provide mobility. Components are enclosed by a weather-resistant metal housing, which is removable in two sections. The housing is suitably equipped with hinged doors to allow access for inspection, servicing, and maintenance. The stand requires connection to a 220/400-volt, 60-Hz, 3-phase, a-c power source for operation of the electric drive motor, fill pump motor, heat exchanger fan motor, and electrical circuitry by means of an external power cable. Connections between the test stand and the aircraft are made with two flexible hoses equipped with suitable quick-disconnect fittings. The operating

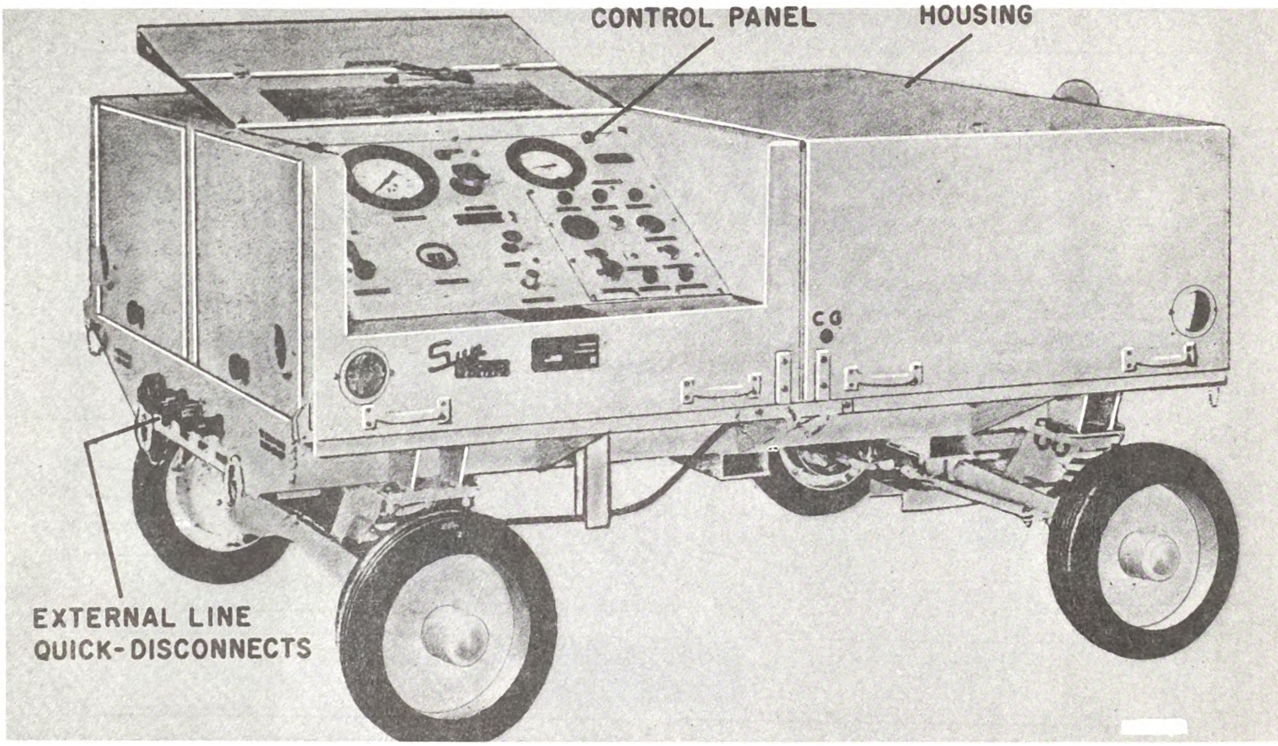


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Figure 14-18.—Side view of Model XMA-75 aircraft hydraulic test stand.

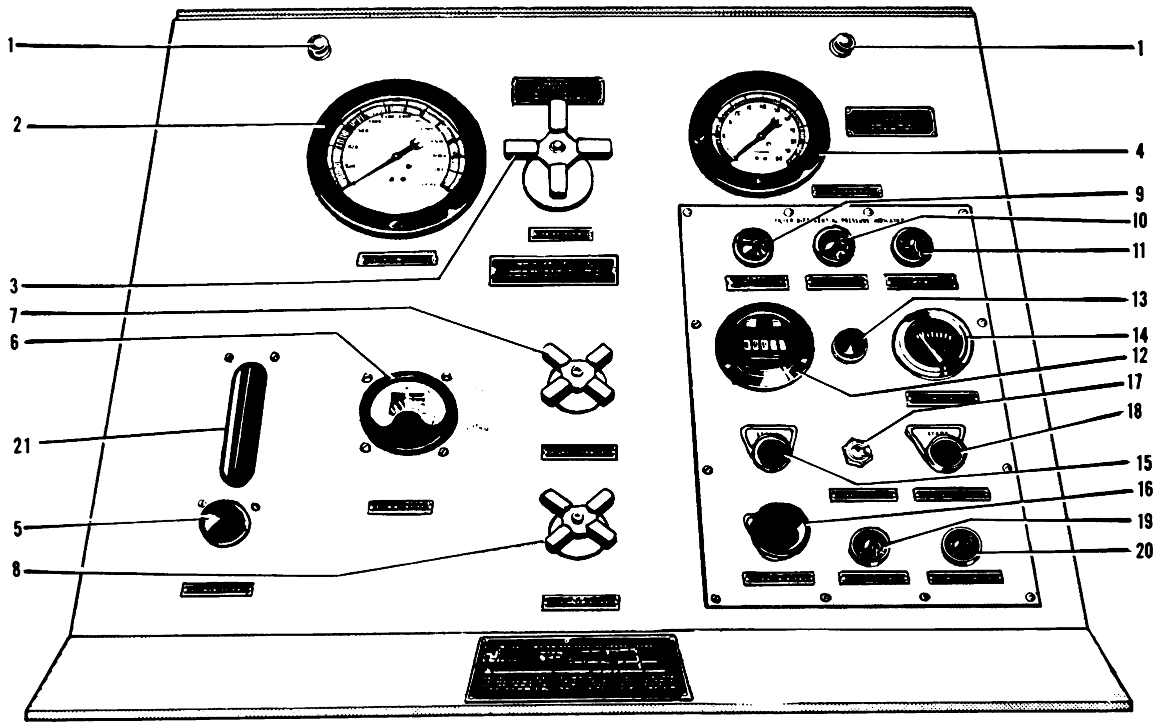
controls and instruments are located on the test stand control panel as illustrated in figure 14-19.

The test stand is capable of operating under ambient temperatures ranging from -20° F to +130° F at a relative humidity of 0 to 100 percent. This test stand system will deliver a fluid volume of 19 gallons per minute (gpm) at a pressure of 3,400 psi or up to 5 gpm at 5,000 psi. Incorporated within the system is a thermostatically controlled heat exchanger installed in the return flow system which dissipates up to 25,000 Btu per hour from the fluid when the stand is operated in 70° ambient temperature at the maximum flow rate. In addition, this stand is designed to perform satisfactorily when inclined up to 15 degrees in any direction from the horizontal.

The Model XMA-75 hydraulic system test stand incorporates three subsystems within the test stand hydraulic system. These systems are the fill system, the low-pressure system, and the high-pressure system.

The fill system is provided for the purpose of filling aircraft hydraulic systems with fluid from the test stand reservoir and to replenish the system with fluid which may be lost during bleeding operations. Basic components of the fill system are the fill pump and fill motor (39, fig. 14-20), adjustable relief valve (2), fill system filter (5), and "Push to Fill" control button (18, fig. 14-19) located on the stand control panel. The fill system pump delivers fluid at a fixed volume of 3 gpm at 140 psi and is driven with a 1-horsepower, 3,450 rpm, drip-proof electric motor. The fill pump is equipped with a magnetic type starter which affords overload protection.

The low-pressure system supplies fluid under conditions of adequate flow and pressure to charge the high-pressure pump. The basic components of the low-pressure system are the



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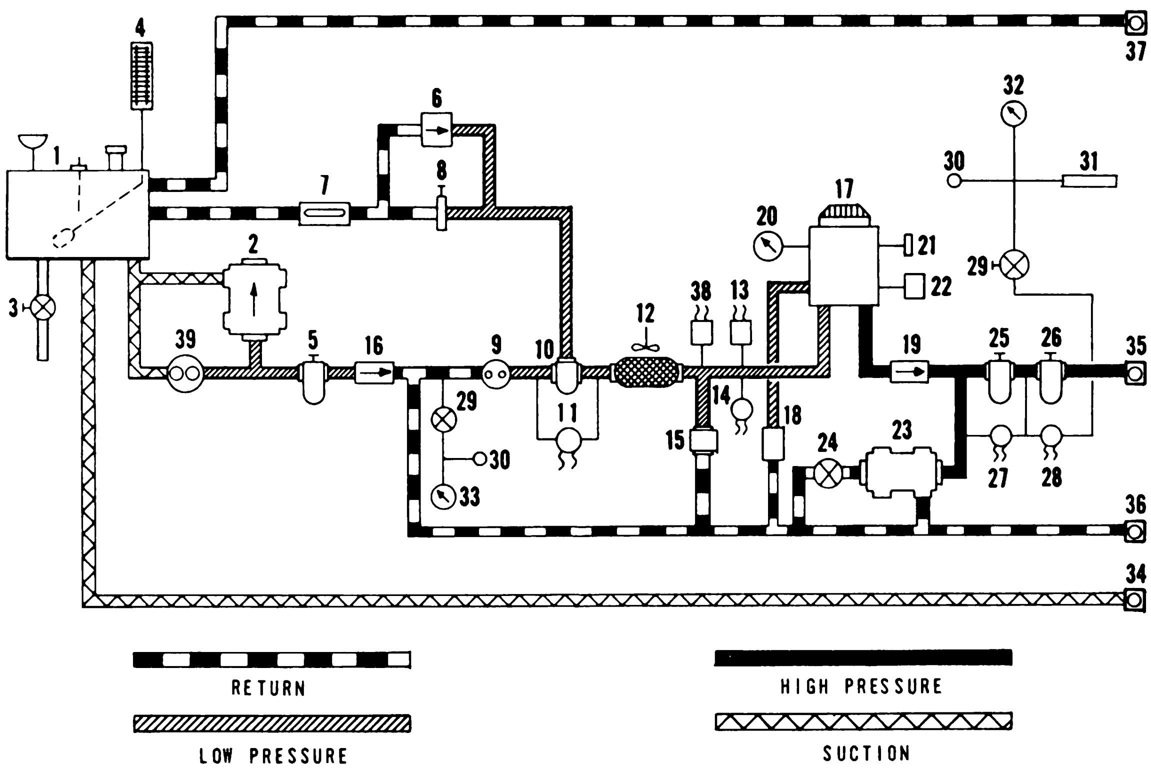
1. Panel lights.
2. Fluid pressure gage.
3. Fluid volume control.
4. Back pressure gage.
5. Filter bleed valve.
6. Pump volume indicator.
7. Compensator control.
8. Fluid bypass valve.
9. Low-pressure filter indicating light.
10. High-pressure filter (2-micron) indicating light.
11. High-pressure filter (10-micron) indicating light.
12. Hourmeter.
13. Power ON indicating light.
14. Reservoir level indicator.
15. Motor control start button.
16. Motor control stop button.
17. Master switch.
18. Fill pump "Push to Fill" button.
19. Low boost pressure indicating light.
20. Fluid high-temperature indicating light.
21. Filter bleed sight tube.

Figure 14-19.—Model XMA-75 hydraulic test stand control panel.

return inlet connection (36, fig. 14-20), boost pump (9), low-pressure filter (10), heat exchanger (12), and low-pressure relief valve (15).

When visualizing fluid flow within the system, the operator can see the fluid being received from the test stand's reservoir (1) or the return inlet connection, depending on which source is being used, and directed to the boost pump. The boost pump pressurizes the fluid and delivers it at a flow of 22 to 24 gpm at a pressure ranging from 100 to 200 psi. This pressurized fluid passes through a 10-micron low-pressure filter and the heat exchanger to



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1. Reservoir.
2. Relief valve (adjustable).
3. Drain shutoff valve.
4. Fill system filter.
5. System filter.
6. Thermal relief valve.
7. Sight tube (bleed).
8. Fluid bleed valve.
9. Low-pressure boost pump.
10. Low-pressure filter (10 micron).
11. Differential pressure switch.
12. Heat exchanger.
13. Thermoswitch.
14. Low-pressure cutout.
15. Low-pressure relief valve.
16. Check valve.
17. High-pressure pump.
18. Check valve (pump case).
19. Check valve.
20. Pump volume indicator.
21. Pump compensator control.
22. Pump volume control.
23. High-pressure relief valve.
24. Bypass valve.
25. High-pressure filter (10-micron).
26. High-pressure filter (2-micron).
27. Differential pressure switch.
28. Differential pressure switch.
29. Gage shutoff valve.
30. Gage test fitting.
31. Pulsation dampener.
32. High-pressure gage.
33. Low-pressure compound gage.
34. Flushing and storage outlet.
35. Outlet connection (HP).
36. Return connection (from aircraft).
37. Flushing and storage inlet.
38. Thermostat.
39. Fill pump.

Figure 14-20.—Model XMA-75 hydraulic test stand schematic.

the inlet port of the high-pressure pump, thus insuring the pump a positive supply of charged fluid.

A pressure differential switch (11) across the low-pressure filter will automatically stop the drive motor if boost pressure falls below safety requirements, and at the same time a red light will illuminate on the test stand's control panel. The drive motor is also stopped by a sensing thermostat (38) if the temperature of the fluid passed through the heat exchanger exceeds 160° F. This also illuminates a red warning light on the control panel. Should the pressure of the fluid to the high-pressure pump inlet exceed limits of charging requirements, the pressure is relieved through the low-pressure relief valve (15) into the return line of the low-pressure system.

The test stand high-pressure system furnishes hydraulic fluid under controlled conditions of flow and pressure to perform the testing operations of the aircraft. The basic components of the high-pressure system consist of a high-pressure pump (17, fig. 14-20), 10-micron high-pressure filter (25), 2-micron high-pressure filter (26), adjustable high-pressure relief valve (23), bypass valve (24), and a high-pressure outlet connection (35).

Pressurized fluid leaving the high-pressure pump flows through the 10-micron high-pressure filter and the 2-micron high-pressure filter. This filtered fluid is then routed through the high-pressure outlet connection to the aircraft hydraulic system.

Operating procedure for the Model XMA-75 begins with a visual inspection. This inspection is performed by a qualified operator prior to connection of the test stand to the aircraft. This inspection is also part of the periodic inspection performed by the ASH at specified intervals. The inspection includes the following steps:

1. Insure that the test stand's reservoir is serviced to the capacity of 20 gallons of MIL-H-5606 hydraulic fluid.

NOTE: Insure that the filler spout strainer is installed during servicing of the reservoir.

2. Open all hinged doors and visually inspect internal components for evidence of leakage.

3. Connect power cable plug to 220-volt, 60-Hz, 3-phase, a-c power source.

4. Position master switch (17, fig. 14-19) to ON. This will illuminate the sight tube back light, the power ON green indicating light (13), and the panel lights (1), and energize the reservoir level indicator (14).

5. Connect the high- and low-pressure hoses to the test stand's pressure and suction outlet and inlet fittings. Leave the other ends of the hose disconnected.

6. Adjust the two gage shutoff valves (located above the external hose quick disconnects and within the test stand housing) one quarter turn from full close.

7. Set the fluid volume control (3) to the amount specified for the aircraft being tested.

8. Turn the compensator control (7) counterclockwise until compression of the spring is released.

9. Close the fluid bypass valve (8).

10. Preset the high-pressure relief valve (located to the left and above the gage shutoff valves) to 3,600 psi.

11. Open the fluid bypass valve.

12. Preset the fill system relief valve to 45 psi.

Prior to connecting the test stand to an aircraft, the stand's hydraulic system must be flushed, filled, and bled of any entrapped air. This is accomplished by observing the following steps:

1. Start the fill pump by pressing and holding the fill pump's "Push to Fill" button (18).

2. Press and hold the filter bleed valve button (5) until no evidence of air appears in the filter bleed sight tube (21).

3. Connect the free end of the high-pressure hose to the stand's flushing inlet connection and the free end of the suction hose to the stand's flushing outlet connection.

4. Press and hold the fill pump button (18) for 1 minute.

5. Start the main pump by pushing the motor start button (15).

6. Press and hold the filter bleed button (5) until no evidence of air is seen in the filter bleed sight tube (21).

7. Stop the main pump by pressing the motor stop button (16).

After the test stand hydraulic system has been filled and bled of air, the unit is ready for connection to the aircraft for operational checks. To place the stand in operation, proceed as follows:

1. Disconnect the high-pressure and suction hoses from the stand flush ports and reconnect them to the appropriate aircraft connections.

2. Check the test stand reservoir level by means of the reservoir level indicator (14, fig. 14-19).
3. Start the main pump by pressing the motor start button (15).
4. Slowly close the fluid bypass valve (8).
5. Set the compensator (7) to the desired pressure as indicated by the fluid pressure gage (2).
6. If the sight tube indicates presence of air in the system, bleed by pressing and holding the filter bleed button (5) until a steady flow of air-free fluid is attained.

Upon the completion of the required tests, the following procedure should be followed to shut down the stand:

1. Open the fluid bypass valve (8).
2. Press the motor stop button (16).
3. Position the master switch (17) to OFF.
4. Disconnect the hoses from the aircraft and store them on the stand hangers without disconnecting from the test stand. If, however, the stand is to remain inoperative for an indefinite period, disconnect hoses from the test stand, secure the hose plugs, and cap the stand's outlet and inlet ports.

Maintenance of Portable Test Stands

Although the maintenance of hydraulic test stands is primarily the responsibility of the ASH, this function requires the coordinated efforts of the ASE, and ASM, and the ASH ratings. The maintenance of the trailer and the hydraulic system is the responsibility of the ASH; however, the maintenance of the power sources and electrical circuitry is the responsibility of the ASM and/or the ASE.

NOTE: Whenever possible, the ASH should take advantage of the training situations presented during these coordinated maintenance efforts. It should be kept in mind that, in addition to his knowledge of structures and hydraulics, the ASH2 must have a thorough knowledge of the electrical and mechanical specialties (ASE and ASM) for advancement to AS1.

Most models of portable hydraulic test stands are provided with Maintenance Requirements Cards (MRC's). These MRC's should be used in conjunction with the applicable Service and Repair Instructions for the inspection and maintenance of this equipment. Maintenance of the trailer includes such items as lubrication of bearings and other moving parts, inspection of structural security, and inspection of tires for wear, cuts, and correct air pressure. Maintenance of the hydraulic system includes servicing the system with clean fluid, inspection for evidence of leaks, security of fittings, and inspection of tubing and flexible hose for wear and defects. The hydraulic system must be given a complete operational check at specific intervals.

Portable hydraulic test stands must be maintained in a satisfactory state of cleanliness. Maintenance records are required for each unit. Precautions must be taken to prevent introduction of external contamination when a system is opened for servicing or removal of a unit. All open lines must be plugged or capped. All disconnect fittings must have polyethylene bags tied over the end fittings when not connected, unless they are provided with protective caps as part of the design.

All age-controlled (deteriorative type) external hoses used between the test stand and the aircraft must be replaced at regular intervals not to exceed 2 years. All age-controlled (deteriorative type) internal hoses are to be replaced at each major overhaul/rework interval not to exceed 4 years.

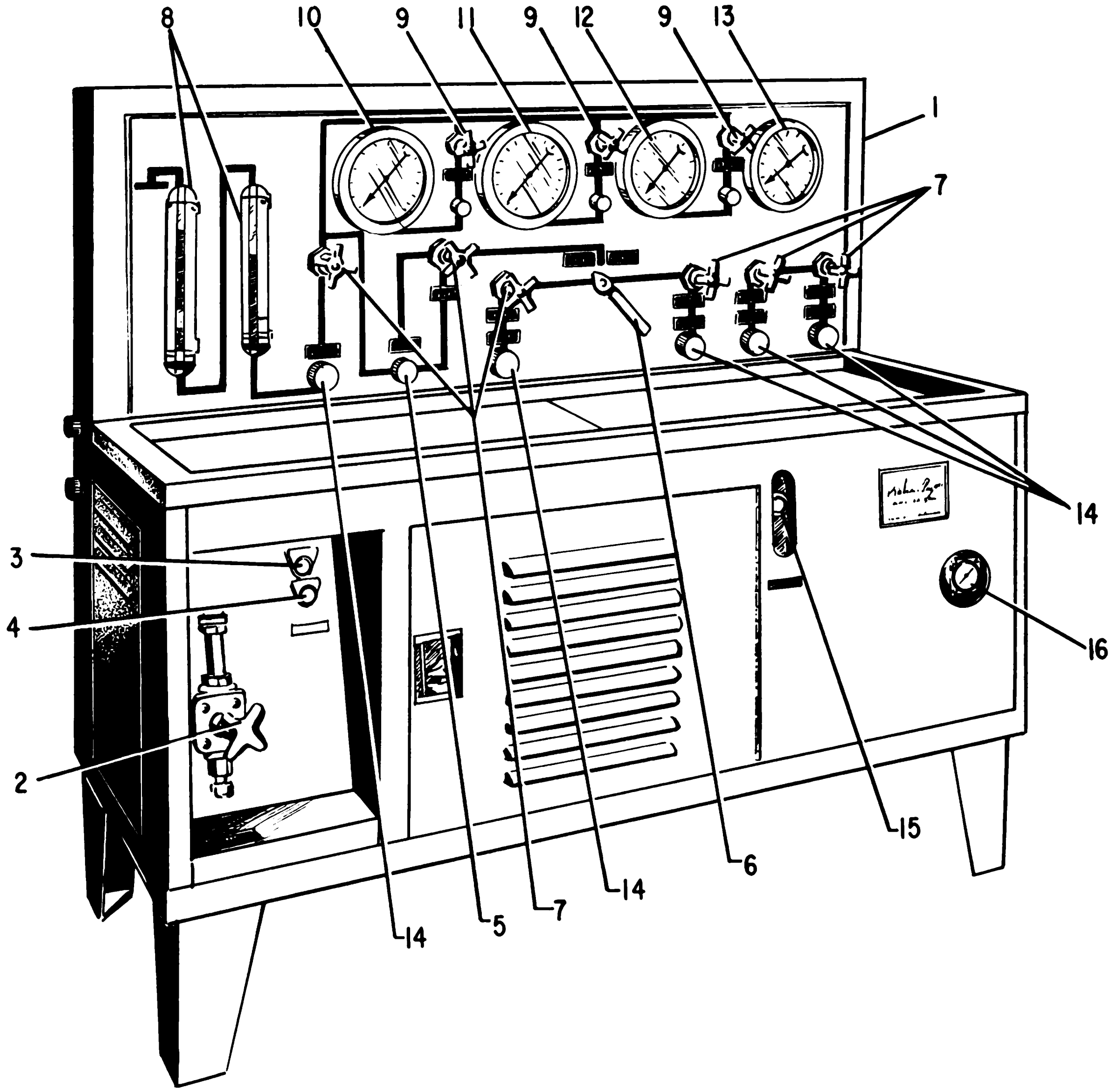
The hydraulic fluid used in operating portable test stands should conform to Military Specification MIL-H-5606-B. This fluid should be replaced with Military Specification MIL-H-6083-C before storing or shipping a test stand.

All hydraulic fluid connections, openings, and fittings on external servicing lines and hoses must be kept clean at all times. Prior to hose quick-disconnect attachment to the aircraft, insure no contaminants are present. All portable test stands must be cleaned and inspected in accordance with existing maintenance instructions.

All filter elements must be replaced as required and at regular intervals, in accordance with existing maintenance instructions. Filter elements must be replaced whenever the differential monitoring device (if so equipped) is activated and/or excessive contamination is evident or indicated during normal operation.

HYDRAULIC COMPONENT TEST STANDS

Another type of hydraulic test equipment in common use is the hydraulic component test bench, commonly referred to as the stationary test stand. Although these test stands are used



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1. Instrument and control panel.
2. Main pump handwheel control.
3. Magnetic starter.
4. Start-stop switch.
5. Pressure relief valve.
6. Four-way valve.
7. Shutoff valve.
8. Flowmeter.
9. Shutoff valve.
10. Gage (0-100 psi).
11. Gage (0-1,000 psi).
12. Gage (0-5,000 psi).
13. Temperature gage.
14. Test connections.
15. Hand pump.
16. Fluid level indicator.

Figure 14-21.—Model 1033 hydraulic component test stand.

primarily for testing aircraft hydraulic system components, they are also used for testing hydraulic components of support equipment. Two models of this type of test equipment are described in the following paragraphs.

Test Stand Model 1033

The Model 1033 test stand, shown in figure 14-21, provides filtered hydraulic fluid for testing hydraulic components functionally, statically, or in cycles. The unit incorporates a 22-gallon fluid reservoir, two pumps (hand and electric-motor driven), three gages for measuring pressure in various ranges, temperature gage, flowmeters, pressure relief valve, etc.

The test stand must be connected to a source of suitable electric power and to a cold water supply and drain lines. The reservoir drain valve outlet may be connected to a waste line if desired.

To avoid injury from misuse, it is important that personnel assigned to operate equipment of this type be thoroughly familiar with the recommended operating instructions. Listed first are some safety precautions which should always be observed.

Be sure to stay within the rated capacity of the test stand. Select the correct gage system for the test pressure to be used and do not exceed the pressure for which the system is designed. Check the temperature of the hydraulic fluid and be sure it does not exceed the specified degrees. Make sure that all outlet ports and control valves which are not to be used in the test are closed. Prior to conducting a static pressure test, bleed all air from the test stand hydraulic system and from the component to be tested.

CAUTION: When a test has been completed, be sure to bleed pressure from the system before disconnecting the hose from the component being tested. Accomplish this by opening the bypass valve.

ADJUSTING THE FLOW.—With the fluid circulating freely through the open bypass valve, adjust the flow as follows for the particular test to be made:

1. Open flowmeter shutoff valve.
2. Slowly close the bypass valve.
3. Adjust the flow control hand knob on the pump until the desired flow is obtained on the flowmeters.
4. Close the flowmeter shutoff valve and open the bypass valve.

ADJUSTING THE PRESSURE.—Pressure adjustments are controlled by the following procedure:

1. Open the shutoff valve to the pressure gage having the required range, after making sure that the pressure outlet valves are closed.
2. Slowly close the pressure bypass valve.
3. Turn the locknut on the relief valve adjusting stem to the left and adjust the opening pressure of the valve to 200 to 250 psi higher than the pressure specified for testing the component. Turn the adjusting screw to the right to raise the pressure and to the left to lower it. Hold the adjusting screw at the desired point and tighten the locknut by turning it to the right.
4. In a similar manner, adjust the pressure valve on the compensator control until the desired test pressure is indicated on the pressure gage. Tighten the locknut.
5. After completing the pressure settings, open the bypass valve and allow the fluid to circulate freely.

NOTE: The compensator control pressure valve must be used to control pressure during the test. The pressure relief valve is set slightly higher in order to protect the test component should the control pressure valve fail to function. Always use the bypass valve to relieve pressure in the hydraulic system.

FUNCTIONAL TESTS.—Having adjusted the test stand hydraulic system to the flow and pressure required for testing a particular component, proceed as follows:

1. Connect the component to a pressure outlet and return port.
2. Open the pressure outlet valve and the return port valve.
3. Turn the four-way selector valve to direct flow to the applicable pressure outlet.
4. Slowly close the pressure bypass valve.
5. When the tests have been completed, remove pressure from the system by opening the bypass valve.

CYCLE TESTS.—With the test stand adjusted for the desired flow and pressure, proceed as follows:

1. Connect the two pressure outlets to the appropriate ports on the test component, and connect the outlet port or ports to the return port(s) in the stand.

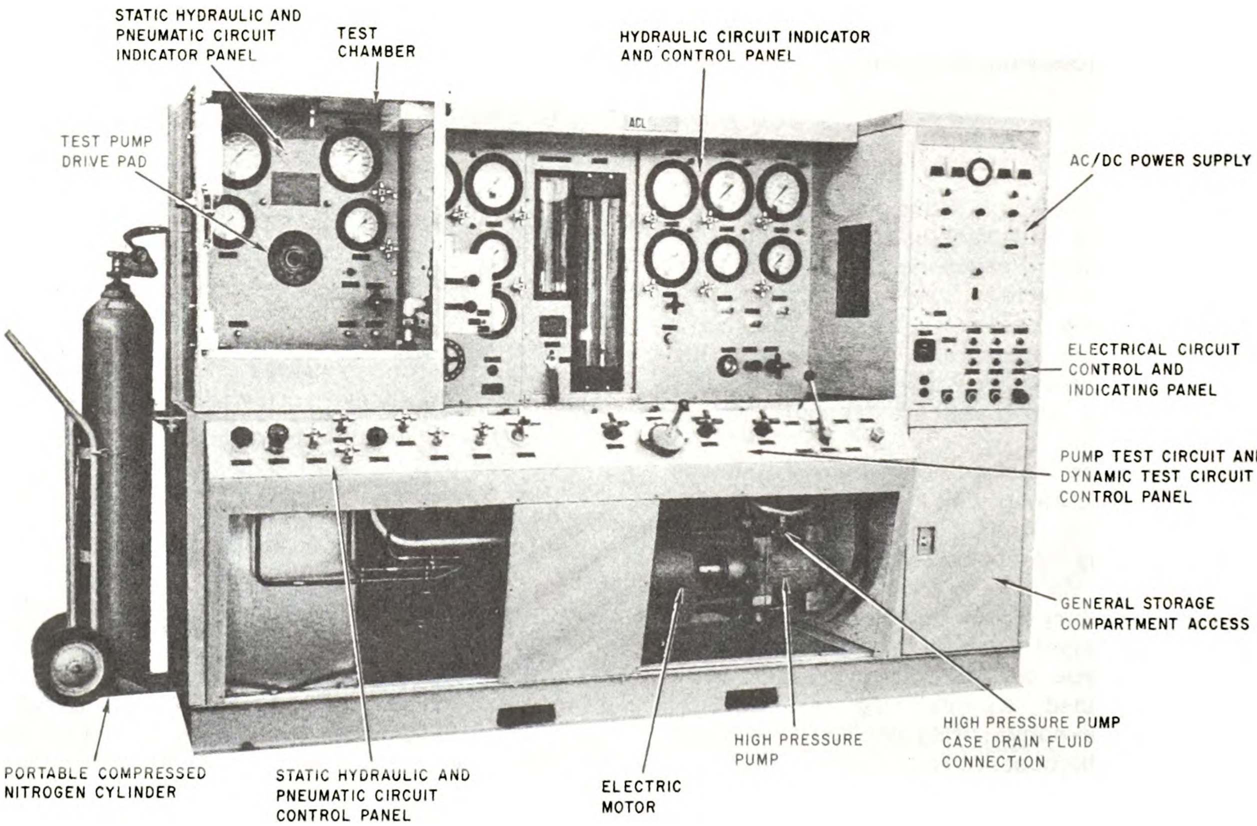

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Figure 14-22.—Model HCT-10 hydraulic and pneumatic component test stand (stationary).

2. With the four-way selector valve in neutral, open the (two) pressure outlet valve(s) and the return port valve(s).

3. Slowly close the pressure bypass valve.

4. Cycle flow to the appropriate pressure outlet by means of the four-way selector valve.

5. When tests have been completed, relieve pressure in the hydraulic system by opening the bypass valve. Close the pressure outlet and return port valves.

STATIC TESTS.—Static tests are to be made by use of the hand pump. Proceed as follows:

1. Make sure that the motor-driven pump is stopped and that the flowmeter shutoff valve and the pressure relief valve are closed.

2. Connect the test component to either pressure outlet and open the corresponding valve.

3. Open the valve for the gage having the desired range.

4. Turn the four-way selector valve to the appropriate pressure outlet.

5. Operate the hand pump and proceed with the tests in accordance with the component specifications.

6. When the tests are completed, relieve pressure from the system by opening the bypass valve.

7. Close the pressure outlet valve.

Test Stand Model HCT-10

The Model HCT-10 test stand, shown in figure 14-22, is used to bench test hydraulic and pneumatic components such as engine-driven hydraulic pumps, double-acting hydraulic

actuating cylinders, pneumatic and hydraulic relief valves, accumulators, and other components.

The test stand consists of a nonportable cabinet assembly containing a hydraulic system, a pneumatic system, and an electrical system. Connections to externally supplied electrical power, water, and compressed air are required.

The cabinet assembly consists of a welded steel enclosure on a rigid base. Hinged doors and removable panels provide access to the interior. The test component work area is located below the center instrument and control panel. The bottom surface of the test component work area and the test chamber is fabricated in the form of a sink with perforated metal trays. The test chamber is fabricated from 1/4-inch steel plate with a hinged door containing a safety type window.

Most of the hydraulic and pneumatic system operating controls are located on a sloping panel along the front of the cabinet. The indicators are located on a panel above the work sink and the rear panel of the test chamber. The electrical system controls and indicators are located on a panel on the right-hand side of the cabinet. A partition separates the major part of the electrical system components from the hydraulic system.

HYDRAULIC SYSTEM.—The hydraulic system is composed of a reservoir supplying fluid through a helical screw type boost pump and a filter to a variable-displacement, pressure-compensated, axial piston, high-pressure pump. The hydraulic system is also composed of three circuits—the dynamic test circuit, the static test circuit, and the pump test circuit.

Dynamic Test Circuit.—The dynamic test circuit is used to test double-acting hydraulic cylinders and other components requiring combined pressure and flow.

Static Test Circuit.—This test circuit is included in the hydraulic system and is essentially a compressed-air operated, low-displacement, high-pressure pump which supplies fluid for static pressure tests. This circuit may be operated independently of the other two test circuits. A safety interlock prevents operation of this circuit when the door of the test chamber is open.

Pump Test Circuit.—The pump test circuit is provided to supply controlled pressure and flow to a variable-displacement, reversible-rotation hydraulic motor that, in turn, supplies power for driving hydraulic pumps during tests.

PNEUMATIC SYSTEM.—The pneumatic system is composed of two circuits. One circuit provides control, indication, and filtration of externally supplied compressed air for the operation of the hydraulic fluid temperature control system and operation of the hydraulic static pressure pump and the pneumatic static pressure booster.

The second circuit consists of a portable compressed nitrogen cylinder which supplies gas to a supply port through a manually adjusted pressure regulator for the purpose of static pneumatic testing. A safety interlock prevents operation of this circuit when the door of the test chamber is open.

ELECTRICAL SYSTEM.—Externally supplied electrical power is controlled by a system located on the right-hand control panel. The test stand START switch, pump ON/OFF switches, and a test stand STOP switch are located along the lower portion on this panel. There is also a test stand STOP switch located on the top left side on the center front of the test stand.

OPERATING PROCEDURE.—To avoid injury to personnel and damage to the components and test stand, it is essential that personnel assigned to operate this test stand be thoroughly familiar with the recommended operating instructions and safety precautions. This information can be found in the applicable Operation, Service, and Overhaul Instructions.

Preliminary Checks and Adjustments.—Prior to the operation of this test stand, preliminary checks and adjustments must be made to insure everything will operate and function properly. Listed below are some of the preliminary checks and adjustments.

1. Hydraulic fluid temperature control adjustment.
2. Pneumatic static circuit check.
3. High-pressure pump check and adjustment.
4. Hydraulic static circuit check and adjustment.
5. Boost pump check and adjustment.
6. A-C/D-C power supply check.

Connections Between Test Stand and Test Component.—The test stand has eight hydraulic fluid ports and two pneumatic ports provided for connection between the test component and the test stand. Listed below are some of the setups and operations that can be accomplished

between the fluid and the pneumatic ports of the test stand and components.

1. Setup and operation of pump test circuit.
2. Setup and operation of dynamic test circuit.
3. Setup and operation of dynamic supply and return circuit.
4. Setup and operation of the hydraulic static pressure test circuit.
5. Setup and operation of the pneumatic static pressure test circuit.

Setup and Operation of the A-C/D-C Power Supply.—To set up and operate the a-c/d-c power supply to provide electrical power to a test component, proceed as follows:

1. Actuate the input power circuit breaker and the D-C and A-C output switches to the OFF position.
2. Rotate the D-C, A-C, and FREQUENCY adjust control knobs to the DEC position.
3. Actuate the input power circuit breaker and the D-C and A-C output switches to the ON position.
4. Adjust the D-C or A-C adjust control knob to the desired operating voltage and the FREQUENCY adjust to the desired operating frequency.
5. Actuate the D-C or A-C output switch to OFF and connect the input leads of the test component to the D-C or A-C output terminals.

CAUTION: The electrical connections between the output of the A-C/D-C power supply and the test component must provide positive connections to minimize the possibility of an accidental interruption of the circuit. Failure to observe this practice could result in injury to operating personnel.

6. Actuate the D-C or A-C output switch to the ON position to energize the electrical circuit of the test component. The current drawn by the test component will indicate on the D-C or A-C AMPS meter. The output voltage or the frequency may be adjusted as required.
7. Deenergize the test component by actuating the D-C or A-C output switch to the OFF position.

CAUTION: Do not use the INPUT POWER circuit breaker as an ON-OFF switch to control the application of power to the test component. Failure to observe this could result in damage to the A-C/D-C power supply and the test component due to high voltage spikes on the output terminals under this condition.

FLUID CONTAMINATION CONTROL

Experience has shown that the cause of most malfunctions in hydraulic systems may be traced to some type of contaminants in the hydraulic fluid. Methods of preventing and controlling the contamination of hydraulic systems are presented in the following paragraphs. This includes the types of contaminants, testing for fluid contamination, and cleaning contaminated hydraulic systems.

HYDRAULIC SYSTEM CONTAMINATION

Contamination is defined as any particle the size of 3 microns or larger. This may be in the form of grit, sand, dirt, rubber, rust, sealants, dust, metal, or any other substance which is not soluble in hydraulic fluid. Likewise, any fluid foreign to the basic system fluid is considered a contaminant.

NOTE: A micron is 0.00004 inch in size. See chapter 13 for more detailed information on the micron and hydraulic system filtration methods.

There are two basic ways to contaminate a hydraulic system. One is to inject particles and the other is to intermix foreign fluids, including water.

Although particle contamination in a system may be self-generated through the normal wear of system components, it is the injection of contaminants from outside which usually cause the most trouble. Regardless of its origination, any form of contamination in the hydraulic system will impede performance and, in some cases, seriously affect safety.

A single grain of sand or grit can cause internal failure of a hydraulic component. This type of contaminant usually stems from poor servicing and fluid handling practices. It is for this reason that the highest level of cleanliness be maintained and observed when performing any maintenance on hydraulic systems or components.

Servicing can be done safely, and contamination held to a minimum, by following just a few basic rules.

1. Never use fluid that has been left open for an undetermined time. Hydraulic fluid that is exposed to air will absorb dust and dirt.
2. Never pour fluid from one container to another, unless servicing a filler unit. The

Table 14-2.—Materials required for contamination analysis.

Material	Specification/P/N
Dry Cleaning Solvent	P-D-680, Type I
Cleaning Compound, Solvent (Freon)	MIL-C-81302A, Type II
Wiping Cloths, disposable	
Can, Metal, 1 gallon	
Can, Safety, 5 gallon	RR-S-30
Kit, Hydraulic Fluid Contamination Analysis	P/N 57L414

hydraulic fluid being transferred may absorb small particles or impurities from the intermediate container.

3. When using a filling unit, insure that it incorporates a filter designed for the specific system for which its use was intended. This filter must be replaced or cleaned at regular intervals, the particular interval depending upon the amount of use and the design of the filling unit.

4. Hydraulic fluid handling equipment must be maintained in a high state of cleanliness.

5. Insure that the correct hydraulic fluid is being used. This can normally be ascertained by inspecting the specification plate on the unit being serviced. Normally, hydraulic fluids are not compatible and should not be mixed. If MIL-H-6083C petroleum based preservation fluid has been used in a system, it must be drained and replaced with MIL-H-5606B, or other recommended fluid, as soon as possible due to their difference in viscosity.

Hydraulic fluid subjected to excessively high temperatures breaks down in substance, leaving minute particles of asphaltine suspended in the fluid. The fluid changes from red to brown in color and is referred to as decomposed fluid. Decomposed fluid must be drained and the system must be flushed and refilled.

Contamination of the hydraulic system may also be caused by wear or failure of hydraulic components and seals. This type of contamination can usually be found through filter inspection and fluid analyzing. Continued operation of a contaminated system may cause malfunctioning or early failure of hydraulic components.

Hydraulic system contamination levels have been established and standards set. SAE Class 5 or better has been adopted as the accepted level of contamination for Navy aircraft and ground support equipment. The means to detect contaminants in fluid has also been established using the Patch Test Analysis Kit, P/N 57L414, and related instructions supplied with the kit.

Patch Test Analysis

The success of contamination patch test analysis for hydraulic fluid systems depends upon performing careful sampling and maintaining clean equipment and solvents in a clean area. Table 14-2 lists the materials required to perform the analysis. Any dirt, particles, or soil which is allowed to contaminate the hydraulic fluid or the equipment will cause erroneous results. However, careful attention to the details of the procedures provided herein will provide useful data for evaluating the condition of hydraulic fluid systems.

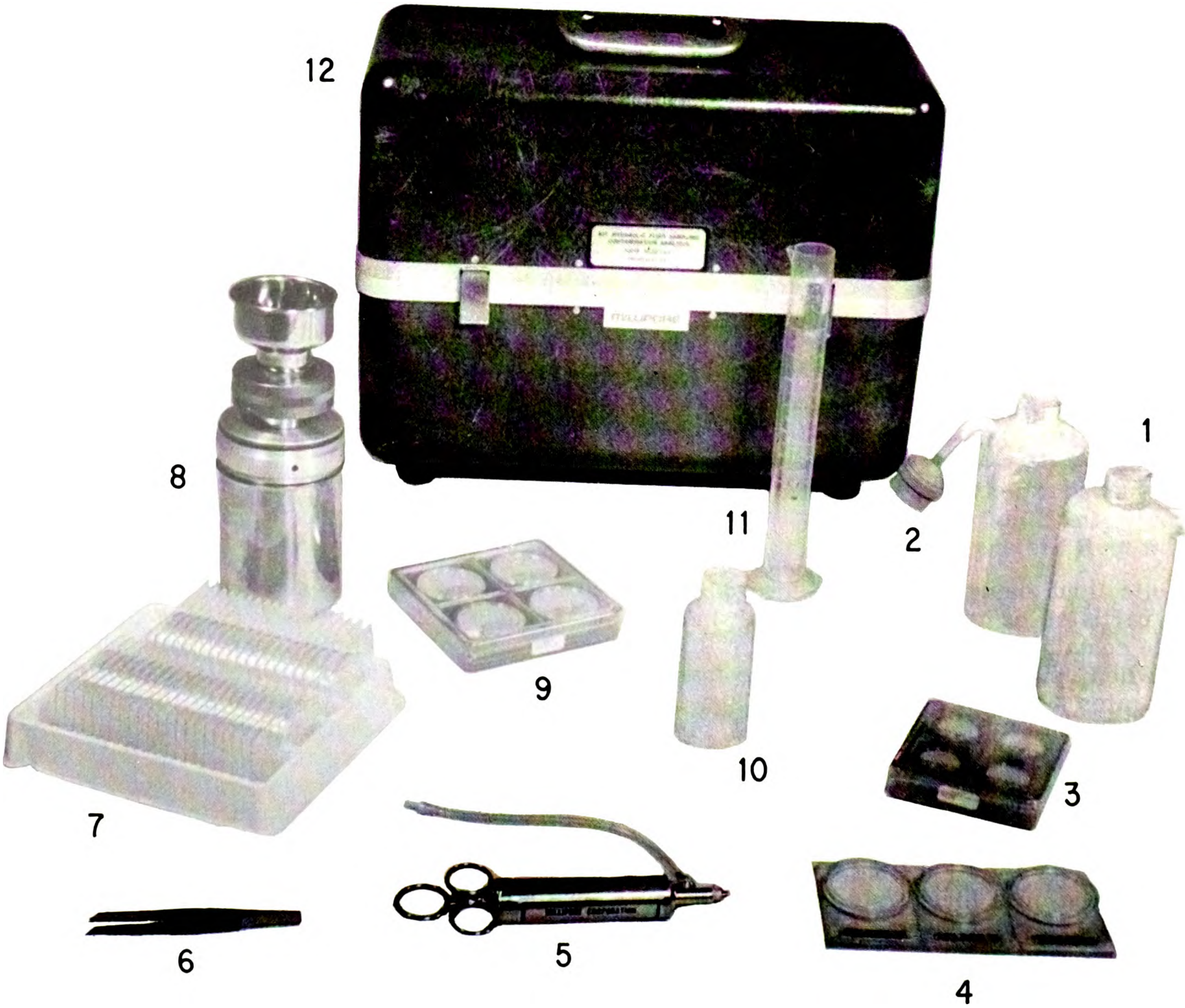
The contamination analysis kit is illustrated in figure 14-23. Preparation for contamination analysis is accomplished as follows:

NOTE: Two plastic wash bottles (item (1), fig. 14-23) are provided in the analysis kit. These two wash bottles are identical, except that one has a shorter tip to accommodate the Swinnex filter unit (2). This bottle is used to dispense filtered solvent when performing analysis of oil or rinsing bottles in preparation for sampling of hydraulic fluid. The other bottle is used to flush fittings on the hydraulic system at sampling points to prevent external contamination.

CAUTION: The filter patches are separated by blue discs in the container. Be careful to discard these separators before installing the filter patch.

1. Disassemble the Swinnex filter holder (2), and install the filter (3) on the perforated surface, using the stainless steel forceps (6), and assemble the Swinnex filter holder fingertight. Do not overtorque.

CAUTION: The tip of the wash bottle may be damaged if the filter holder is forced on too tight. If this does happen, the other wash bottle may be modified by carefully cutting off the tip with a sharp knife or razor blade so the filter holder will fit. The damaged bottle may then



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1. Bottle, wash, polyethylene, 500 millileter (ml); tip modified on one to accept Swinnex filter holder.
2. Swinnex filter holder.
3. Filters, white, plain, 25mm.
4. Standard, hydraulic fluid contamination patches.
5. Syringe, metal with two-way valve.
6. Stainless steel forceps.
7. Petri-slides.
8. Filter holder assembly.
9. Filters, white, plain, 47mm.
10. Bottle, polyethylene, 4 oz., narrow-mouth.
11. Cylinder, graduated, TPX.
12. Contamination analysis kit.

Figure 14-23.—Contamination analysis kit.

be used for general flushing of the system fittings.

2. Fill the wash bottle with Freon solvent, MIL-C-81302, Type II, and replace the screw cap. Freon is the preferred solvent for analysis because it evaporates more readily and patches dry more rapidly. However, drycleaning solvent may be used for analysis work

if sufficient drying time is allowed. Attach the Swinnex filter unit to the wash bottle delivery tip. Cover the hole in the cap with your finger and by squeezing the bottle, filtered solvent will be delivered as required.

3. Wipe off the fitting or component which is to be sampled. Use disposable wiping cloths and rinse with clean drycleaning solvent, P-D-680, Type I, dispensed from the plastic wash bottle. Clean, unused jet engine fuel, JP-5, may be used as an alternate solvent. Loosen the fitting to allow fluid to flow from the connection.

CAUTION: Avoid contamination from outside of the system since this does not represent the true condition of the system and may lead to erroneous results and unnecessary delay of the equipment.

4. Flush off the fitting again with drycleaning solvent. Allow to drain.

5. Complete the disconnection as required. If at all possible, allow a portion of hydraulic fluid to flow from the sampling connection before taking the sample. Loosen the cap of the sample bottle (10), so that it can be removed easily.

6. Collect at least a 4-ounce sample in the sample bottle (10). Replace the cap and label. Where less than 4 ounces of fluid is available, such as filter bowls, collect as much as possible.

7. Identify the samples as follows:
   Equipment Model No.
   Serial No.
   Source of sample

NOTE: When filter bowl or similar samples are taken, be careful that a sample representative of the contents of the bowl is transferred to the sample bottle.

8. Continue sampling until all samples required for the service unit have been taken. Be sure samples are properly labeled. Samples collected and identified as specified must be filtered and examined for contamination.

NOTE: Steps 9 through 14 detail the analysis procedure.

9. Assemble the filter holder assembly as shown in (8) of figure 14-23. Connect the plastic hose (5) to the side of the filter flask and to the vacuum (intake) side of the syringe (5).

10. Unlock the filter funnel (8) and install a clean filter patch (9), using the stainless steel forceps (6). Be sure to remove the blue separators. Lock the funnel assembly and pour approximately 25 milliliters of filtered Freon solvent into the funnel.

11. Mix the sample by inverting the bottle several times. Measure 100 milliliters of fluid sample into the graduated cylinder (11) and pour into the funnel containing the 25 milliliters of Freon solvent. Begin filtering by pumping the syringe. This creates a vacuum which will hold for several minutes.

12. Rinse the cylinder with 50 milliliters of solvent to remove all residue and pour into the funnel. Repeat, using another 50 milliliters of solvent. Apply more vacuum by pumping the syringe as required.

13. While some fluid remains in the funnel, wash down the sides of the funnel with filtered solvent from the squeeze type wash bottle. Do not direct the spray from the wash bottle directly onto the filter patch.

14. Apply vacuum again and dry the filter for 2 to 3 minutes. Remove the filter patch and allow to dry in still air in an uncovered petri-slide (7). Cover the patch, label, and evaluate. Whenever drycleaning solvent, P-D-680, is used as the filtered solvent, patches must be allowed to dry thoroughly before putting them in the petri-slide, otherwise the slide will craze and cloud.

Steps 15 through 17 detail the evaluation of the samples.

15. Samples usually are taken from specified filter bowls and from system reservoirs. Filter patches from filter bowls will generally be evaluated for the presence of metal and for other types of nonmetal contamination. Reservoir samples will generally be evaluated against an SAE Class 5 standard patch only. All systems should be evaluated for water. Water droplets can be detected on filter patches.

16. Examine filter patches and evaluate for visible metallic and nonmetallic particle contamination to determine if the system meets the requirements as specified for the specific ground support equipment. Compare the appropriate filter patches with the standard patches (4) provided with the kit. Systems whose patches are darker than the Class 5 standard patch are unsatisfactory. Systems whose patches are equal to or lighter than the Class 5 standard are acceptable.

17. Perform decontamination procedures and resampling in accordance with specific directives for the ground support equipment unit.

As a guide to particle contamination levels, table 14-3 outlines the Navy Standard for Hydraulic Fluids. Remember, particle level Class 5 or better, meaning 4, 3, 2, 1, or 0 are

Table 14-3.—Navy standards for aircraft and GSE hydraulic fluids.

Micron size range	Particle contamination level - by class						
	0	1	2	3	4	5	6
	Total number of particles/100 milliliters sample						
5-10	2,700	4,600	9,700	24,000	32,000	87,000	128,000
10-25	670	1,340	2,680	5,360	10,700	21,400	42,000
25-50	93	210	380	780	1,510	3,130	6,500
50-100	16	28	56	110	225	430	1,000
Larger than 100	1	3	5	11	21	41	92

accepted levels for aircraft and ground support equipment.

CONTAMINATION CONTROL

Filtering devices installed at strategic locations in the hydraulic system provide adequate control of the contamination problem during normal operation. Precautions must be taken by maintenance personnel to prevent the entry of foreign particles into the systems during maintenance. Such precautions include making certain that new fluid added to reservoirs and fluid used for flushing the system is clean. In addition, every portable hydraulic test stand must be equipped with nonbypass type filters with an absolute rating of 3 microns or less, before operation with an aircraft hydraulic system to prevent contamination of the aircraft hydraulic system.

Should the filtering devices of the fill stand or portable test stands become excessively contaminated, the filter elements must be removed and cleaned by ultrasonic methods. Where ultrasonic cleaners are not available, new filter elements must be installed.

In the list below are some of the DO's and DON'Ts that will aid and assist in the elimination and control of contamination of hydraulic systems.

DO's.—

1. Assure can is clean prior to opening.
2. Always open can from unpainted end.
3. Always throw away remaining fluid in opened can.
4. Crush and throw away empty can to prevent reuse.
5. Assure use of proper: Fluid, O-rings, lubricants, and O-ring installation techniques.
6. Store O-rings, fittings, and components in clean packaging.
7. Check filters if system runs dry or if pump malfunctions. If system is contaminated, change filter elements and flush the system.
8. Flush system if contamination is suspected.
9. Use metal plugs in female ports.
10. Use metal caps on male fittings.
11. Use plastic caps over "B" nuts.
12. Properly cap lines and components.
13. Have replacement component available, if possible, prior to disassembly.
14. Have clean working areas.
15. Use clean, lint free rags.
16. Perform required periodic checks on servicing equipment.
17. Assure proper hose storage on ground support equipment (portable hydraulic test stands).
18. Assure disconnect dust covers are connected.

19. Keep fluid in servicing reservoir above 1/4 full.
20. Store caps and plugs in clean area.

DON'Ts.—

1. Break into system unless absolutely necessary.
2. Reuse fluid drained from system or component.
3. Substitute required: Fluid, O-rings, lubricants, or filter elements.
4. Use can opener to open cans containing other fluids or materials.
5. Retain fluid in open container.
6. Service any reservoir directly from newly opened can.

NOTE: This is especially important when servicing the hydraulic reservoirs of aircraft and aircraft hydraulic test stands. A filler unit should always be used to service these systems. If a filler unit is not available or is impractical to use, the hydraulic reservoirs of other items of support equipment may be serviced from a newly opened can. When servicing reservoirs in this manner, particular attention should be paid to items 1, 2, 3, 4, 15, and 19 listed under DO's and items 2, 4, 5, and 10 listed under DON'Ts.

7. Use improper tools—causes chips.
8. Operate test stand if filter warning light is ON.
9. Use plastic plugs in female ports.
10. Expose fluid to atmosphere longer than necessary.

CLEANING HYDRAULIC SYSTEMS

Throughout the Navy, three standards have been adopted for cleaning or changing fluid in hydraulic systems—recirculation cleaning, flushing, and purging.

Recirculation Cleaning

Recirculation cleaning is a decontamination process accomplished by circulating the original fluid through the system and filters, replacing or cleaning these filters, as required, throughout the cleaning operation.

Flushing

Flushing is a decontamination process in which the original fluid is removed to the maximum extent practical and discarded. New replacement fluid is then added as required.

Purging

Purging is a decontamination process in which the hydraulic system is drained to the maximum extent practical and the removed fluid discarded. A suitable cleaning agent is then introduced into the system and circulated as effectively as possible so as to remove gross contaminants. The operation is completed by removing the circulated cleaning agent and replacing it with new working fluid. Purging is usually followed by a period of recirculation cleaning to insure adequate decontamination.

CHAPTER 15

BRAKES AND BRAKE SYSTEMS

Efficient and reliable brakes are just as important to powered support equipment as the engine. They are not only required to stop the vehicle, but must stop it in as short a distance as possible and then hold it in place after it is stopped. Because brakes are expected to decelerate a vehicle at a faster rate than the engine can accelerate it, they must control a greater power than that developed by the engine.

The requirement for good brakes is not limited to powered equipment. Such nonpowered equipment as oxygen and nitrogen servicing trailers, air-conditioning units, bomb trailers, and workstands are equipped with some type of braking system. While the primary purpose of the brakes on powered equipment is to stop the vehicle, their primary purpose on nonpowered equipment is to secure the equipment after it has been pushed or towed to the desired location.

A brake absorbs mechanical energy by transferring it into heat through friction. Friction is the resistance to relative motion between two surfaces in contact with each other. Thus, when a stationary surface is forced into contact with a moving surface, the resistance to relative motion or the rubbing action between the two surfaces will slow down the moving surface.

In nearly all brake systems the brake drums provide the moving surface and the brake shoes the stationary surface. The friction between the brake drum and the brake shoe slows the vehicle, and the friction between the tires and the road surface adds to the friction, bringing the vehicle to a complete stop.

This braking action is accomplished through rods and cables in a mechanical brake system, a liquid coupling (brake fluid) in a hydraulic brake system, and air pressure in a pneumatic brake system. A combination of hydraulics and pneumatics (or vacuum) is used to operate the brakes of some items of equipment. Although electrical systems are used to operate some brake systems, they are not commonly used on ground support equipment.

The ASH is responsible for the maintenance of the brakes and brake systems on all ground support equipment. This includes servicing, inspection, adjustment, and repair. To accomplish these tasks, he must have a thorough knowledge of the various types of brakes and brake systems and their operation. The first section of this chapter describes the different types, the operation, and the maintenance of brake assemblies, and the remainder is devoted to the different types of systems used to control the brake assemblies.

BRAKE ASSEMBLIES

Powered support equipment is equipped with either two or four wheel brakes. In either case, individual brake assemblies are provided for each braking wheel and are operated by a foot pedal. Powered equipment also has an emergency or parking brake which is operated by a separate pedal or lever. This may be a separate brake assembly (transmission parking brake which is discussed later) or it may simply be a secondary method of controlling the wheel brake assemblies. The brake assemblies on nonpowered equipment are similar to those on powered equipment but are usually provided only on two wheels.

TYPES

Brake assemblies may be classified into two general types—external contracting and internal expanding. There are different designs of the internal expanding type of which the conventional shoe is the most common type used on support equipment. The expander tube brake, which is another design of the internal expanding type, is used on some types of equipment. These three types of brake assemblies—external contracting, internal expanding (shoe), and internal expanding (expander tube)—are described in the following paragraphs.

External Contracting

Figure 15-1 shows an external contracting brake. The brake band is anchored opposite

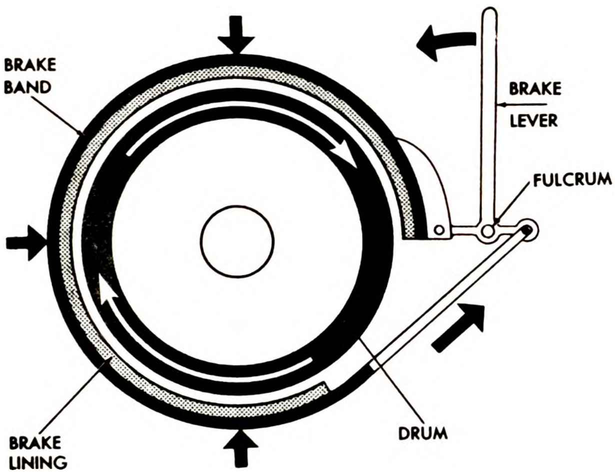

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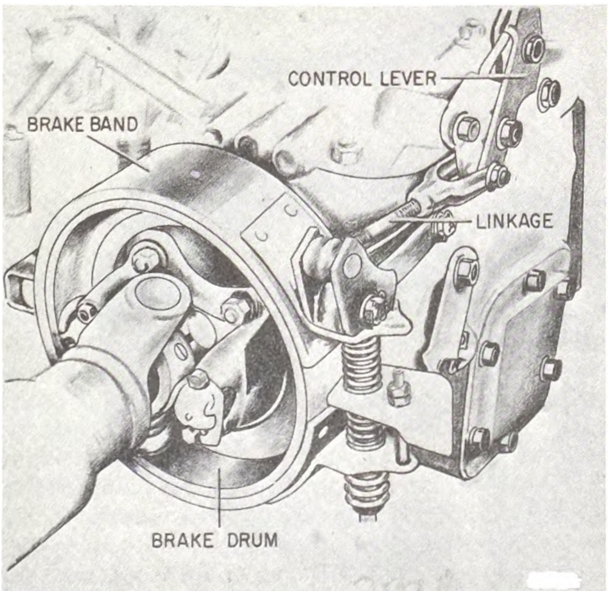
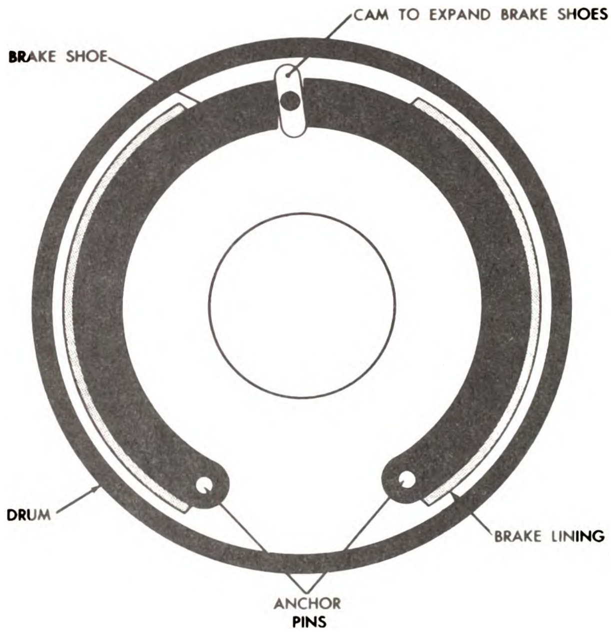
Figure 15-1.—External contracting brake.



AS.734
Figure 15-2.—External contracting transmission parking brake.

the point where the pressure is applied. In addition to supporting the band, the anchor provides a means for adjusting brake lining clearance. Other adjusting screws and bolts are provided at the ends of the bands.

In operation, the brake band (or shoe) of the external contracting brake is tightened around the rotating drum by moving the brake control



AS.735
Figure 15-3.—Internal expanding brake.

lever. Moving the lever in the opposite direction forces the band away from the drum, thus releasing the brake. Most brakes of this type are provided with a release spring. When the brake is applied the movement of the control lever also compresses the spring. When the brake lever is released the spring tension forces the brake band away from the drum.

The brake band is made of comparatively thin, flexible steel, shaped to fit the drum, with a frictional lining riveted to the inner surface. This flexible brake band cannot withstand the high pressure required to produce the friction that will stop a heavily loaded or fast moving vehicle. In addition, when used as wheel brakes, external contracting brakes are exposed to dirt, water, and other foreign matter. This exposure causes the brake linings to wear and to decrease in frictional properties. For these reasons external contracting brakes are rarely used for wheel brakes. They are often used, however, as parking brakes. Figure 15-2 shows the external contracting brake used as a transmission parking brake. The brake drum is located at the point where the drive shaft is attached to the rear of the transmission.

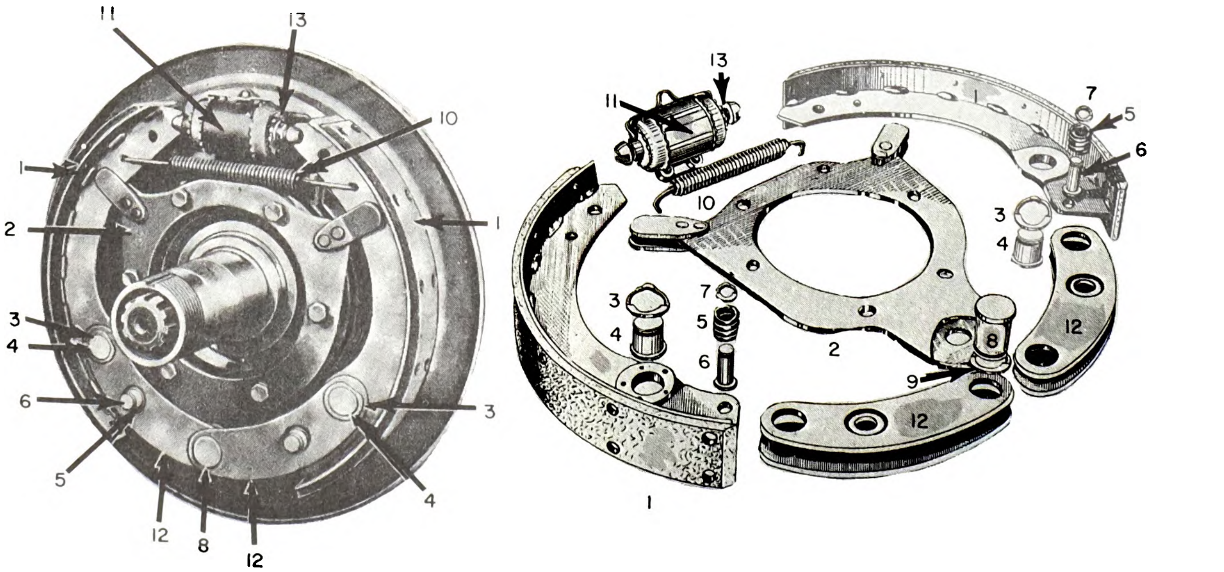
Internal Expanding (Shoe)

Internal expanding brakes are used almost exclusively as wheel brakes. This type permits a more compact and economical construction. The brake shoe and brake operating mechanism are supported on a backing plate or brake shield which is attached to the axle flange in the case of nondriving axles or to the axle housing in the case of driving axles. The brake drum, attached to the rotating wheel, acts as a cover for the shoe and operating mechanism and furnishes a frictional surface for the brake shoes. Figures 15-3 and 15-4 show the arrangement of the brake shoe and operating mechanism of a typical wheel brake assembly.

In operation, the brake shoe of an internal expanding brake is forced outward against the drum to produce the braking action. One end of the shoe is hinged to the backing plate by an anchor pin, while the other end is unattached and can be moved in its support with the operating mechanism. When force from the operating mechanism is applied to the unattached end of the shoe, the shoe is forced (expands, hence the term expanding) against the drum and brakes the wheel. A retracting spring returns the shoe to the original position when braking action is no longer required.

The brake-operating linkage alone does not provide sufficient mechanical advantage for positive braking. Some means of supplementing the physical application of the braking system is used to increase pressure on the brake shoes. A self-energizing action is very helpful in accomplishing this, once setting of the shoes is started by physical effort. While there are variations of this action, it is always obtained by the shoes themselves, which tend to revolve with the revolving drum.

Figure 15-5 illustrates the self-energizing action of a brake shoe. As shown, the drum is



AS.736

1. Brake shoe and lining.
2. Front brake shoe anchor plate assembly.
3. Front brake shoe link pin lock.
4. Front brake shoe link pin.
5. Pin spring.
6. Pin.
7. Pin lock.
8. Anchor pin.
9. Anchor pin lock.
10. Front brake shoe return spring.
11. Front brake shoe wheel cylinder.
12. Front brake shoe link.
13. Adjusting wheel.

Figure 15-4.—Wheel brake assembled and exploded view.

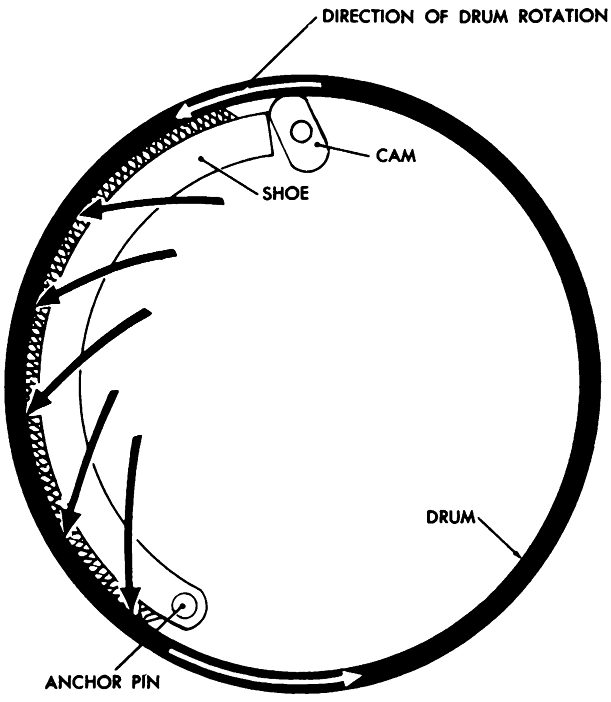


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Figure 15-5.—Brake shoe self-energizing action.

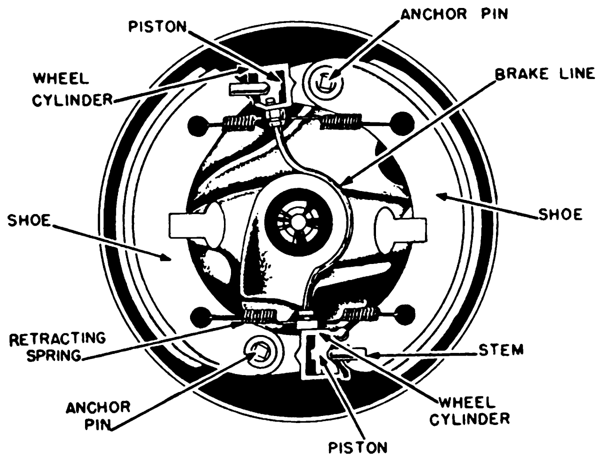

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Figure 15-6.—Front wheel brake assembly.

revolving counterclockwise. When the shoe is forced against the drum, it tends to rotate with the drum. As the initial braking pressure is increased on the cam, the wedging action increases and the shoe is forced more tightly against the drum to increase friction. This self-energizing action results in more braking action than could be obtained with the actuating force alone. Brakes making use of this self-energizing principle to increase pressure on the braking surface are known as servo brakes. (Servo is the action or device used to convert a small movement into a greater movement or force.)

The self-energizing action is controlled by the operator; that is, as additional pressure is applied to the brake pedal, the self-energizing action increases. Thus, it is most important that the operator control the total braking action at all times. The amount of self-energizing action available depends mainly upon the location of the anchor pin. This is determined by the manufacturer and is located at the point outward of the braking surface where the operator has the maximum control of the braking action. If the anchor pin is located too near the center of the drum, the shoe will automatically lock when the brakes are initially applied.

When two shoes are anchored on the lower part of the brake shield, self-energizing action is effective on only one shoe. The other shoe tends to revolve away from its pivot, which reduces its braking action. When the wheel is revolving in the opposite direction, the self-energizing action is produced on the opposite shoe.

With the arrangement shown in figure 15-6, both shoes are positioned to develop self-energizing action with forward movement of the vehicle. For this reason, the arrangement is used mostly on the front wheels where maximum braking effort is required during normal forward movement. In reverse, this arrangement would not have any servo action.

Two shoes are usually arranged so that self-energizing action is effective on both, regardless of the direction of drum rotation. This is accomplished by pivoting the shoes to each other and leaving the pivot free of the brake shield. The only physical effort required is for operating the first, or primary, shoe. Both shoes then apply additional pressure to the braking surfaces with no increase in the pressure on the operating linkage. The anchor pins are fitted into slots in the free ends of the brake shoes.

This method of anchoring allows the movement of the shoes necessary to expand against

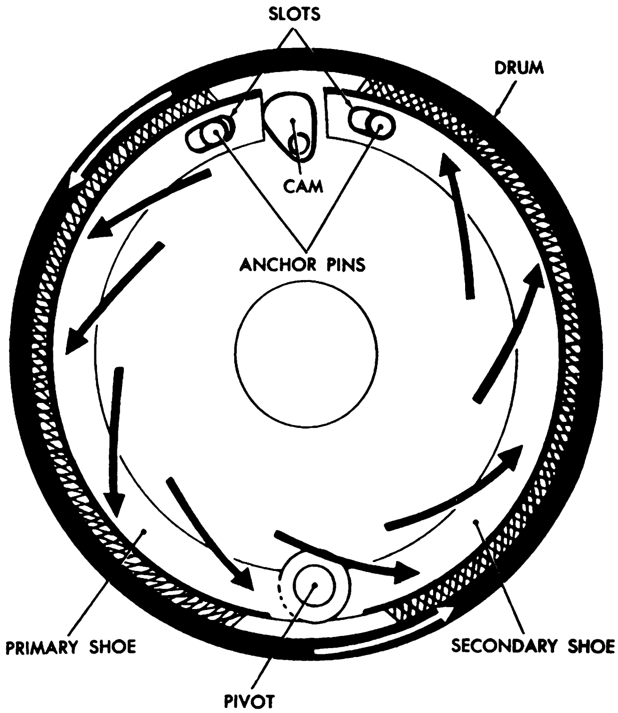

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Figure 15-7.—Primary and secondary brake shoes—self-energizing action.

the drum when the shoes are forced against the drum, and the self-energizing action of the primary shoe is transmitted through the pivot to the secondary shoe. (See fig. 15-7.) Both shoes will tend to revolve with the drum and will wedge against the drum through the one anchor pin. The other anchor pin will cause a similar action when the wheel is revolving in the opposite direction.

Internal Expanding
(Expander Tube)

As mentioned previously, the expander tube brake is used on some types of support equipment. For example, the MRS-190 aircraft tow tractor and the AERO 46A and AERO 47 weapons loaders are equipped with expander tube brakes. It may be noted that the technical manuals for these items of equipment frequently refer to this brake as the aircraft type expander tube brake. This is because the expander tube brake was designed originally for aircraft. Several models of naval aircraft were equipped with this type brake. Some models that are still operational, for example the P-2, are equipped with expander tube brakes.

An exploded view of an expander tube brake is illustrated in view (A) of figure 15-8. View (B) shows the brake completely assembled and view (C) shows a cross-sectional view of the assembled brake. The main parts of the brake are the spider, frame, expander tube, brake blocks, and return springs.

The spider, sometimes referred to as a flange or torque flange, is the basic unit around which the brake is built. The main part of this spider is secured to the wheel support. The detachable metal frames form a groove around the outer circumference into which the expander tube, brake blocks, springs, etc., are fitted.

The expander tube is made of neoprene reinforced with fabric, and has a metal nozzle through which hydraulic fluid enters and leaves the tube.

The brake blocks are made of materials quite similar to that used in the linings of shoe type brakes. The actual braking surface is strengthened by a metal backing plate. The blocks are held in place around the spider and are prevented from rotating by the torque bars which are secured to the frames. The size of the brake assembly varies with different types of equipment. As the size of the assembly changes, the number of blocks per assembly changes. For example, each brake assembly of the MRS-190 tow tractor contains 12 blocks, while each assembly of the AERO 46A weapons loader contains 7 blocks.

The brake return springs are semielliptical or half-moon in shape. One is fitted between each separation in the brake blocks. The ends of the springs are designed to fit into slots in the brake frames. The bowed center section of the spring pushes inward, holding the blocks firmly against the expander tube. (See fig. 15-8 (C).) This prevents the blocks from dragging against the drum when the brake is released.

The expander tube brake assembly is hydraulically operated and may be used with any of the conventional hydraulic brake systems described later in this chapter. When the brake pedal is applied, the fluid is forced into the expander tube. The spider and frames prevent expansion inward or to the sides. Thus, the pressure of the fluid in the tube overcomes spring tension and forces the blocks radially

outward against the brake drum, creating friction. The tube shields prevent the expander tube from extruding between the blocks, and the torque bars prevent the blocks from rotating with the drum. Friction created by the brake is directly proportional to brake line pressure.

When the brake pedal is released, the return springs return the blocks inward, compressing the expander tube and forcing the fluid back to the brake control unit.

BRAKE LINING

There are several important qualities that are desired of the material for brake linings. First, of course, it must have high frictional qualities. Second, the material must have the ability to withstand high temperatures. Since there is a lack of cooling facilities around the brake assembly, it is necessary that the brake lining be able to dissipate the heat rapidly. In addition, the material must be durable and moisture resistant.

Two main types of brake linings are organic and metallic. One form of organic lining is woven material composed of asbestos fiber, cotton fibers, and copper or bronze wire. It is treated with a mineral base chemical to resist the effects of oil and water. It is then pressed and undergoes a baking process that compresses the fibers into a dense material, helping the lining to resist the effects of heat from friction.

This material has a very high frictional quality but a low rate of heat transfer or dissipation. Also, it is severely affected by oil, even after treatment. Therefore, the woven material is used mostly on transmission brakes.

Another form of the organic type is the molded lining. This lining is made of a dense, hard, compact material and is cut into various forms so as to fit different types of shoes. Generally, the compact materials are resins and mineral fibers, mixed as a semiliquid, molded, pressed, and baked. The result is an extremely dense material. Very often copper or bronze wires are added to the mixture.

The frictional qualities of this type lining are lower because of the smooth surface, but it dissipates heat rapidly and wears longer than the woven type. As a result, the molded lining is more suitable for application on the wheel brakes than are the woven types. Because of the density of the molded material, it is less affected by oil and water.

Metallic brake lining is made of finely powdered iron, copper, or graphite, and lesser amounts of inorganic fillers and friction modifiers. The mixture is put through a briquetting process and compressed into the desired form. Metallic brake lining is used when extreme braking conditions exist. The frictional characteristics of metallic lining are more constant than those of organic lining.

The lining may be secured to the shoes by riveting or by a bonding process in which the linings are glued to the shoe. In the bonding process, pressure and heat are applied to make a secure bond between the lining and the shoe. The bonding process allows the lining to be worn comparatively thin without danger of cutting or scarring the drum. When brass rivets are used to secure the lining to the shoe, the lining must be replaced when it is worn to a specified amount to keep from scarring the drum.

BRAKE DRUMS

Brake drums are made of pressed steel, cast iron, or a combination of the two metals. Cast iron drums dissipate the heat generated by friction more rapidly than steel drums, and have a higher coefficient of friction with any particular brake lining. However, cast iron drums are heavier and are not as strong as steel. Quite often, steel drums have a cast iron liner fused into them to provide the necessary strength and heat dissipating qualities. (See fig. 15-9.) To further add to the strength and heat dissipation, cooling ribs are sometimes used on the outside of the drums.

ADJUSTMENT

Brake assemblies require adjustment from time to time. This is due to normal wear of the brake lining, which results in excessive clearance between the lining and the drum. Adjustments must be made to compensate for this lining wear. Also, if one wheel locks before the others are stopped, the driver may lose steering control of the vehicle. It is important, therefore, that brake adjustments be made to provide equal distribution of brake action to all wheels.

When a brake is correctly adjusted the lining attached to the brake shoes should fit evenly against the brake drums when the brakes are applied. Also, the lining must be free of

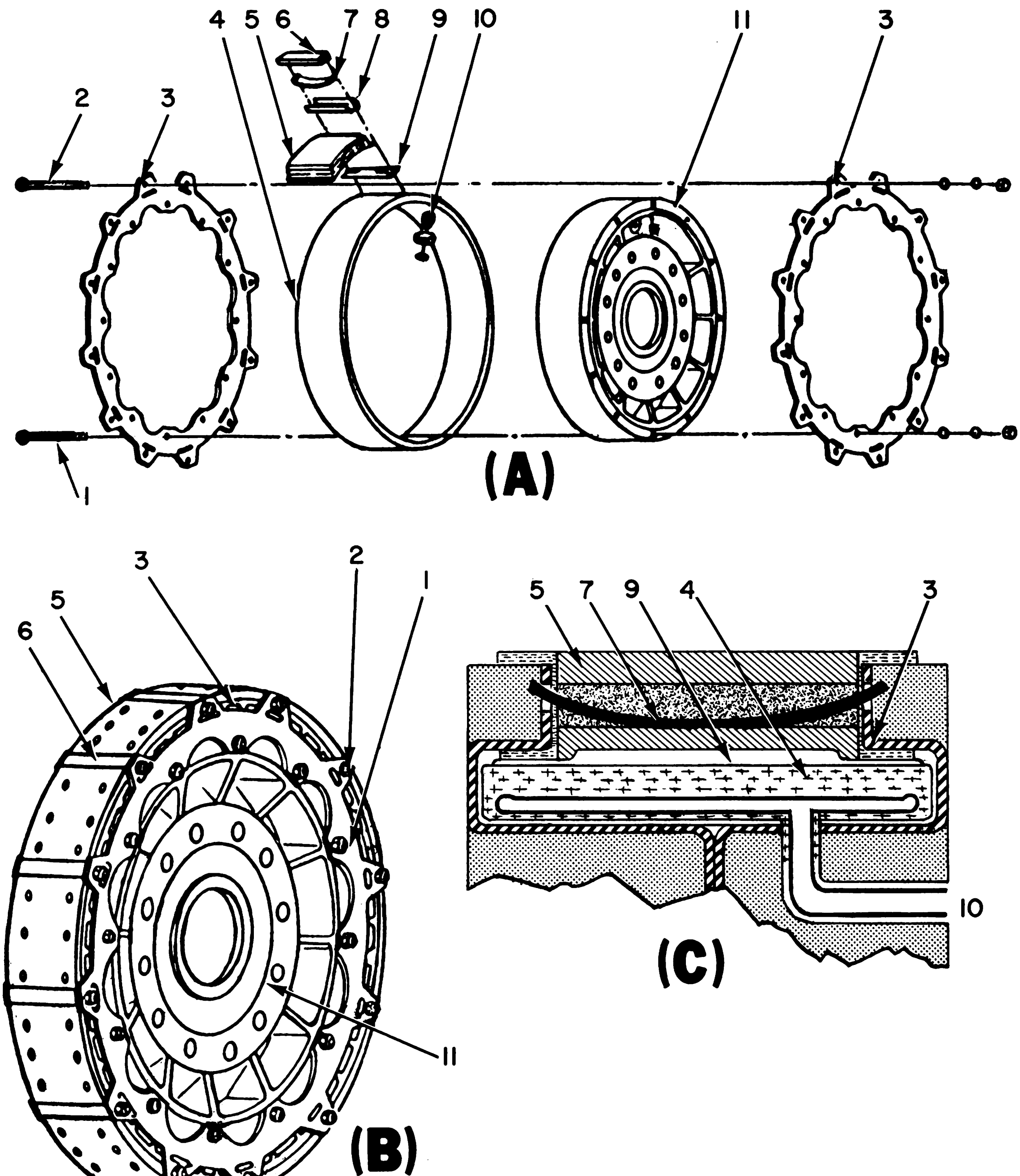

Figure 15-8.—Expander tube brake. (A) Exploded view; (B) assembled view; (C) cross-sectional view.

Nomenclature for Figure 15-8

1. Brake frame bolt.	7. Return spring.
2. Torque bar bolt.	8. Return spring shield.
3. Frame.	9. Tube shield.
4. Expander tube.	10. Inlet port.
5. Brake block.	11. Spider.
6. Torque bar.	

the drum when the brakes are released. The linings must not drag against the drum, yet they must be near enough to give the proper leverage between the operating mechanism and the friction surfaces.

The backing plate of some brake assemblies contains small slots for the purpose of checking these clearances with a feeler gage. However, on most equipment the required clearance is obtained through the following adjustment procedures. (Adjustment procedures for pneumatic brakes are covered later in this chapter.)

NOTE: Brake adjustment procedures vary slightly with different types of equipment. Therefore, the appropriate Instructions Manual must be consulted for making these adjustments.

Before making any brake adjustments, the vehicle must be raised until the wheel rotates freely. (Chapter 11 lists the safety precautions which must be complied with during jacking and hoisting operations.) Brake adjustments are made by turning the hexagon stud at the rear upper section of the brake backing plate. (See fig. 15-10.)

Each stud controls a cam which moves the unattached end of the shoe either toward or away from the drum. Work with one adjusting stud at a time. Turn the adjusting stud in the direction indicated until the lining pressure on the brake drum can be felt. Try to turn the wheel. If the wheel rotates, tighten the adjusting stud until the wheel can no longer be turned. Back off the adjusting stud slowly until the wheel can be rotated. Then back off the adjusting stud an additional one-half turn. (This distance varies on different brake assemblies.) Repeat this procedure with the other adjusting stud. This completes the adjustment for one brake assembly. The complete procedure must then be performed on the other brake assemblies of the vehicle.

As previously stated, some types of powered equipment are provided with transmission parking brakes. (See fig. 15-2.) This type brake is usually operated with a hand lever; therefore, it is often referred to as a hand brake. The

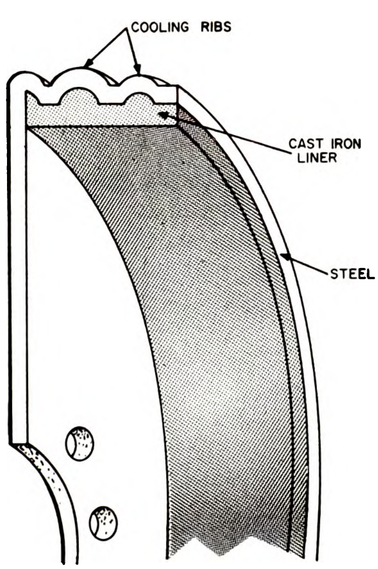

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Figure 15-9.—Sectional view of brake drum.

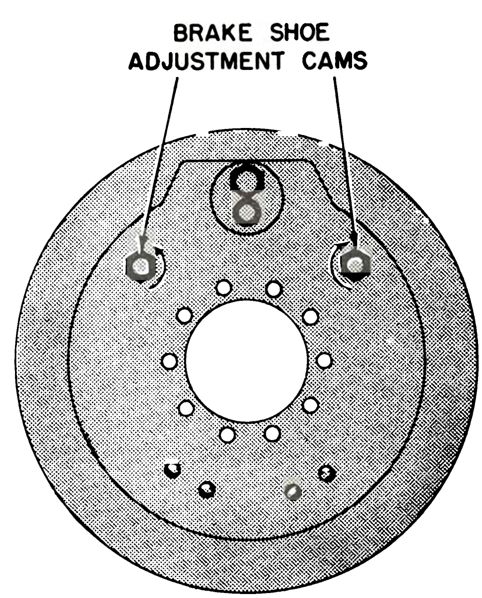

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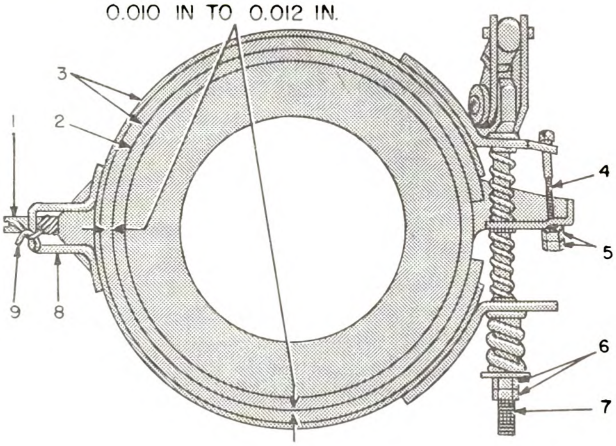
Figure 15-10.—Brake assembly adjustment.



1. Anchor screw.
2. Drum.
3. Band.
4. Bracket adjusting screw.
5. Locknuts.
6. Locknuts.
7. Adjusting bolt.
8. Anchor clip.
9. Lockwire.

Figure 15-11.—Hand brake (transmission parking brake) adjustment.

following are the adjustment procedures for the hand brake. (Refer to fig. 15-11.)

NOTE: The applicable Instructions Manual should be consulted before attempting to adjust the hand brake on an item of equipment.

1. Set the hand brake lever in the fully released position.
2. Remove lockwire (9) from the anchor screw (1).
3. Adjust anchor screw until there is 0.010- to 0.012-inch clearance between the drum (2) and the band (3) at the anchor clip (8).
4. Install lockwire through the anchor clip (8) and the screw (1).
5. Back off locknuts (6) at adjusting bolt (7) until free.
6. Back off bracket adjusting screw locknuts (5).
7. Adjust bracket adjusting screw (4) until there is 0.010- to 0.012-inch clearance between the drum (2) and the bottom of the band (3).
8. Tighten locknuts (5).
9. Turn adjusting bolt locknuts (6) down until the bracket adjusting screw (4) is just relieved of tension.
10. Lock adjusting bolt locknuts (6).

Some types of expander tube brakes are equipped with clearance adjusters. However, the types found on support equipment are not usually equipped with any means to adjust brake clearance. When the brake blocks wear to the extent that the brake clearance is in excess to the maximum specified in the applicable technical manual, the blocks must be replaced.

INSPECTION AND MAINTENANCE

Frequent brake inspections are necessary to insure safe operating conditions. Brake inspections are not made just to comply with regulations but to insure safety of men and equipment. Defective brakes are a contributing factor to many accidents that might have been avoided with frequent and thorough brake inspections.

Like most components of support equipment, brake assemblies require both operational and visual inspections. The interval of these inspections is usually specified in the applicable Instructions Manual and Maintenance Requirements Cards. The operational check is usually conducted daily.

On nonpowered equipment, this can be accomplished by attempting to move the vehicle with the brakes set. Similarly, emergency or parking brakes of powered equipment can be checked by applying power to the wheels with the brakes set.

A road test is usually conducted for the operational check of the wheel brakes of powered equipment. The brakes must stop a moving vehicle in a reasonable distance. After the vehicle is stopped, the brake marks on the roadway should be inspected to see if there is an indication of any one wheel braking more than the others. If the brakes do not stop the vehicle within the prescribed distance, are not equalized, grab, or do not hold, the necessary adjustments or repairs must be accomplished.

The wheel brake assembly must be visually inspected at specified intervals. To accomplish this and required maintenance of the brake assembly, the wheel and brake drum must be removed. The brake assembly should be checked for loose or broken brake shoe retracting springs, worn clevis and cotter pins in the brake operating mechanism, and indications of grease or oil leaks at the wheel bearing grease retainer.

In the case of hydraulic brake systems, the hydraulic brake cylinder should be checked at this time. Inspection and repair of hydraulic wheel cylinders are discussed later in this chapter. The condition of the brake linings and brake drum must be checked thoroughly at this time.

Brake linings which are riveted to the brake shoe should be replaced if worn to less than 40 percent of their original thickness. Also, the shoes must be relined if a rivet head is riding or is about to make contact with the brake drum. If the lining is bonded to the shoes, the remaining lining must be at least 1/16-inch thick.

Brake linings that pass inspection for wear must be securely fastened to the brake shoes and free from grease and oil. Small grease or oil spots can be removed from the lining with an approved cleaning fluid. If the lining is saturated with grease or oil, it must be replaced. The source of grease and oil on the lining must be located and remedied.

If the brake lining needs replacing the brake shoes must be removed. Before the shoes are removed, the front and rear shoe should be marked so that they will be replaced in their original position. The brake shoes may be removed by first removing the brake shoe return spring and the anchor pin locks. (See fig. 15-3.)

Replacing Riveted Type Brake Lining

To remove old lining with a relining machine, replace the rivet set with the rivet punch, and the rivet bucking attachment with the rivet receptacle. After removing the rivets and old lining, remove all burrs from the surface of the shoes. If a relining machine is not available, a drift or pin punch and a bench or table vise can be used to remove the old lining. Most shops, however, will be equipped with a brake relining machine.

To reline the brake shoe, clamp the new lining tightly to the shoe at several places with small C-clamps. If no C-clamps or special holding devices are available, start riveting the new lining to the shoe from the center and work alternately toward the ends. The first two rivets will align the lining with the shoe.

It is important to use the proper size and type of rivets to reline brakes. A rivet head which is too large or too small will not fit properly in the countersunk hole of the lining and, if not the proper length, cannot be clenched securely to the brake shoe.

Replacing Bonded Type Brake Lining

When replacing bonded lining on a brake shoe, the old lining must be carefully removed and the metallic surface of the brake shoe must be thoroughly cleaned. The adhesive or cement for bonded brake lining may be applied in several ways, depending on the type of lining used. Some bonded lining may require cement placed directly on the lining. Others may have tape interposed between the lining and the shoe. Still other linings have a bonding material that has been applied at the factory. Regardless of the type of bonding material, it is necessary to clamp the lining tightly to the shoes in a specially made bonding machine that bakes the lining so that it will stick firmly to the brake shoe.

When replacing a brake lining be sure your hands are dry and free of greases and oil. Even a slight trace of grease on the lining may cause poor braking that would require installation of another lining.

Fitting Brake Shoes

After the brake shoes are relined, the contact surface of the lining should be roughened to remove the glassy finish caused by handling. The abrasive wheel on the relining machine is used for this purpose, as well as for tapering or beveling the lining ends. A slight bevel at the ends of the lining will insure a proper adjustment when the brake shoes are replaced on the vehicle.

The brake shoes are replaced in the original position by reversing the procedure used in removing them. Make sure the anchor pin locks are tight. Check the tension of the retracting springs to see that they hold the unattached ends of the shoes securely in the brake operating mechanisms. After the brake drum is installed the brake must be adjusted.

Maintenance of Expander Tube Brakes

Maintenance of the expander tube brake consists primarily of bleeding (discussed later), replacing brake blocks, or replacing the expander tube.

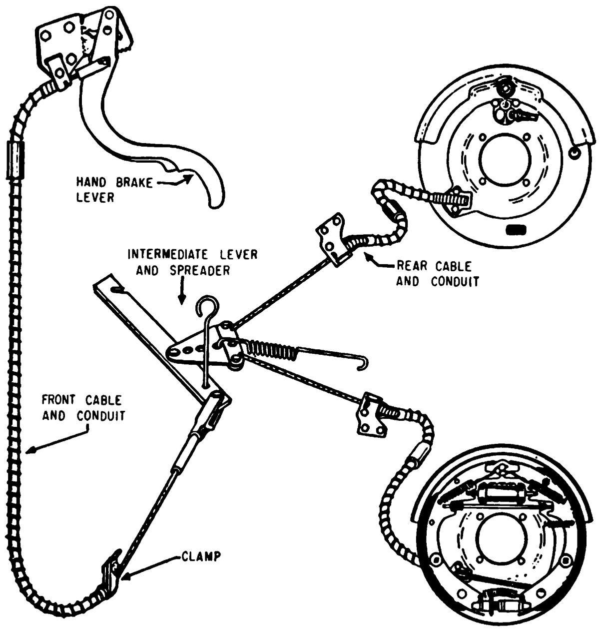


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Figure 15-12.—Mechanical brake system—cables.

As mentioned previously, the brake blocks must be replaced when the brake clearance is in excess of the maximum specified. In this case, the blocks are replaced as a complete set. Sets, which include blocks and springs for the specific model brake, are usually available as replacement kits through supply.

Broken blocks may be replaced individually, but if a considerable number must be replaced, it is advisable to replace the complete set. When individual blocks are replaced, the thickness of the new block(s) should be reduced to approximately that of the remaining blocks. This can be accomplished by grinding the new blocks. Any slight differences in the thicknesses of the blocks may be ignored. After the first few applications of the brakes, the thicker blocks will wear down to the average thickness of the remaining blocks.

Any time that a block is removed from the expander tube brake, the expander tube should be thoroughly inspected for signs of charring or overheating and replaced if necessary. Some manufacturers recommend that the expander tube should be replaced each time the complete set of blocks are replaced.

CAUTION: Do not attempt to operate the expander tube brake when it is not enclosed by the brake drum. To do so will cause the tube to be blown out with consequent damage to the brake blocks, springs, frame, and possible injury to personnel.

Brake Drums

For good braking action, brake drums should be perfectly round and have a uniform surface. Excessive pressure exerted by the brake shoes and heat developed by their application often cause the brake drums to become out of round. Drums should be inspected for distortion, cracks, scores, roughness, and excessive glaze which lowers braking efficiency.

Light score marks can be removed with emery cloth. When the surface becomes badly scored or out of round, it may be reground in a lathe to a true and smooth surface. Excessive grinding will remove too much material from the drum, leaving it too thin and weak. When this occurs, the drum must be replaced. Also, a drum which is cracked or badly distorted should be replaced.

BRAKE SYSTEMS

Although brake assemblies and brake drums are similar on all equipment, the operating mechanism differs with the brake systems. The two most common types of brake systems used on support equipment are the mechanical and the hydraulic systems. Pneumatic and air-over-hydraulic systems are used on some equipment. These four systems are discussed in the following paragraphs.

MECHANICAL BRAKE SYSTEMS

Brakes operated entirely by mechanical linkages from the brake pedal or lever are called mechanical brakes. The mechanical linkages may consist of levers, rods, cables, or any combination of these.

Application

Equalizing brakes, so that all brakes will be applied at the same time, has been a problem of mechanical brake systems, particularly on vehicles having brakes on all four wheels. For this reason, mechanical brake systems are seldom used for the operation of the wheel brakes

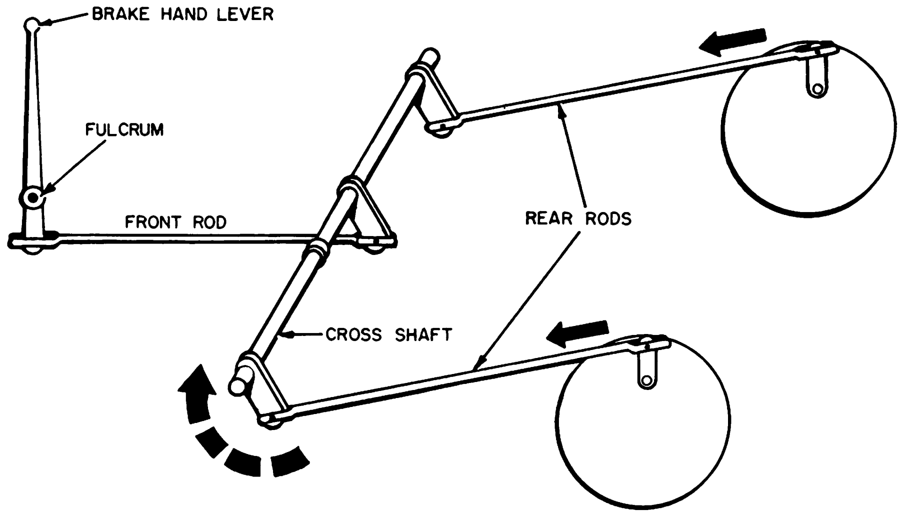

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Figure 15-13.—Mechanical brake system—rods and shaft.

of powered support equipment. They are used, however, for transmission or parking brakes of these vehicles. In fact, most external contracting brakes are operated by mechanical brake systems.

In regards to support equipment, the major use of mechanical brake systems is on nonpowered equipment. Almost all items of nonpowered equipment which require brakes are equipped with some form of mechanical brake system.

Components and Operation

Figure 15-12 illustrates a typical mechanical system for the operation of parking or emergency brakes. This is simply a secondary means of controlling the rear wheel brakes. Variations of this arrangement are used to operate the parking brakes on some powered support equipment.

A cable assembly is the main working element of this system. A single cable connects the control lever to the intermediate lever and spreader. From here two cables complete the connection to the two rear wheel brake assemblies. Large portions of the cable slide within a flexible conduit. This conduit not only serves as a protective housing for the cable but also provides a means for securing the cable to the frame with clamps.

When the brake lever is pulled, the cables are moved and operate levers in the two rear-wheel mechanisms. The levers, as they operate, force the brake shoes apart and in contact with the drum. The intermediate lever and spreader tends to equalize the tension of the two cables to the brakes. This action in turn tends to equalize the braking action of the two brakes. When the hand lever is moved in the opposite direction the cable moves and releases the brakes.

Transmission parking brakes (fig. 15-2) are usually operated by a similar cable mechanism. However, only a single cable, such as the one labeled front cable and conduit in figure 15-12, is necessary for this operation.

Cable assemblies are also used to operate the brakes on some nonpowered support equipment. However, many items of this type equipment are provided with mechanical brake systems similar to the arrangement illustrated in figure 15-13. To apply the brakes, the brake lever is moved to the right which, in turn, moves the front rod forward. This rotates the cross shaft clockwise, moving the rear rods forward. This action rotates a cam in each brake assembly (fig. 15-3) forcing the brake shoes apart and in contact with the drum. The

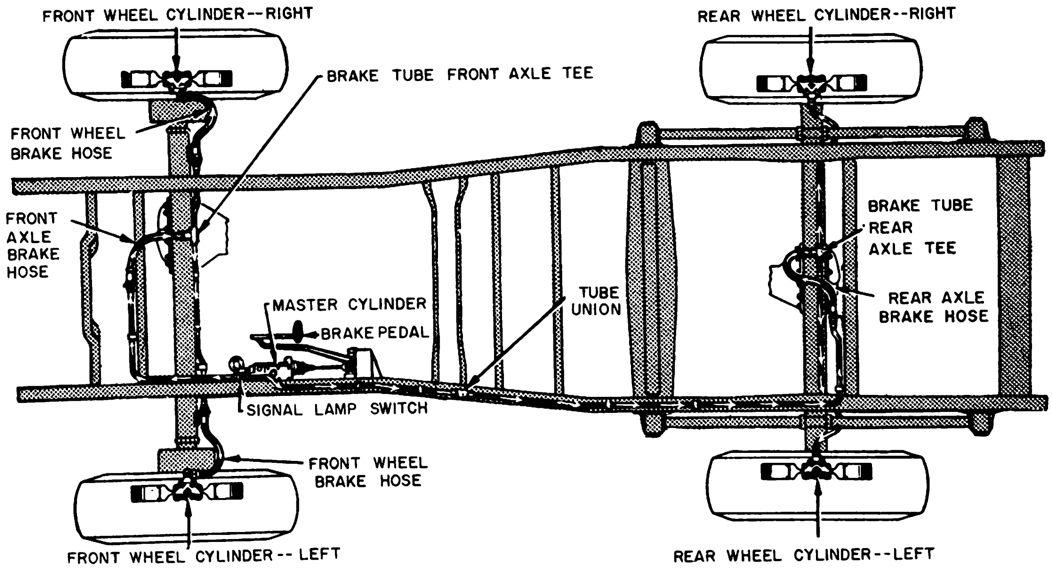

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Figure 15-14.—Typical hydraulic brake system.

brakes are released when the hand lever is moved in the opposite direction.

There are many variations of this arrangement found on support equipment. Cables are sometimes used instead of either or both the front and rear rods. On some equipment the hand lever and cross-shaft may be located directly over the wheels. The control device on some equipment may be a foot pedal rather than a hand lever.

On some models of towed equipment the control linkage for the brakes is attached to the tow bar. With the tow bar in the horizontal position the brakes are released. When the tow bar is placed in the vertical position the linkage moves and applies the brakes. These models are usually equipped with a hand lever or foot pedal to apply the brakes when the tow bar is in the horizontal position.

Inspection and Maintenance

Mechanical brake systems require very little maintenance. However, they must be inspected periodically. Inspections include an operational check of the control device and visual inspection of the mechanical linkage. Special attention should be given to such possible discrepancies as frayed cables, bent rods and shafts, and loose fittings and clamps. The entire system should be inspected for signs of rust and corrosion. Maintenance includes replacement of defective parts, servicing with required lubricants, securing loose clamps and fittings, and straightening bent rods and shafts.

HYDRAULIC BRAKE SYSTEMS

A hydraulic brake system is primarily a liquid connection or coupling between the brake pedal and the individual brake assemblies.

Application

The effectiveness and reliability of hydraulic brake systems have been proven through their extensive use on automobiles for over 30 years. As a result, hydraulic systems are the most common systems used for the operation of the wheel brakes on powered support equipment. The hydraulic brake system on some late models of equipment is provided with a vacuum- or air-booster. These systems are described later in the chapter under vacuum and air-over-hydraulic brake systems.

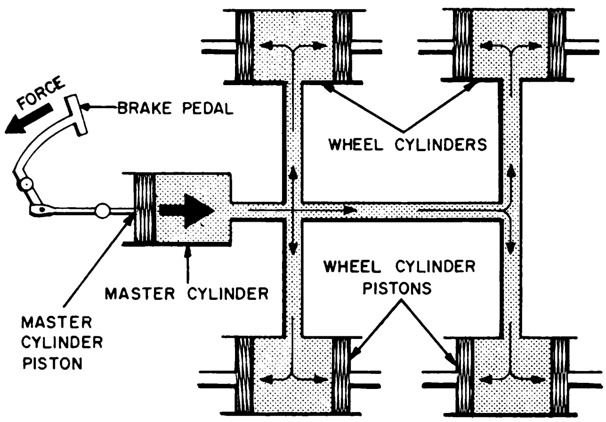

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Figure 15-15.—Operation of hydraulic brake system.

Components and Operation

Figure 15-14 illustrates a typical arrangement of a hydraulic brake system. This system is very similar to the hydraulic systems described in chapter 14. The system consists of a master cylinder connected by tubing and flexible hose to the wheel cylinders. The master cylinder serves as the fluid reservoir, the system pump, and the control valve. The wheel cylinders are the actuators.

A nonpetroleum base fluid is normally used in the brake systems of support equipment. The applicable Instructions Manual should be consulted to insure that the correct brake fluid is used.

Figure 15-15 shows the operation of a hydraulic brake system. Depressing the brake pedal moves the piston within the master cylinder, thus developing fluid pressure. This buildup of pressure forces fluid from the master cylinder into the fluid lines and the wheel cylinders.

Like all liquids, brake fluid for all practical purposes is noncompressible. Therefore, the pressure originated in the master cylinder is transmitted equally to the wheel cylinders. This pressure, applied at the wheel cylinders, causes the pistons to move outward. This pressure overcomes the tension of the retracting springs and forces the shoes against the drums. As the pressure on the foot pedal is increased, greater pressure is built up within the wheel cylinders and, consequently, greater force is exerted against the shoes.

When the pressure on the pedal is released, the brake shoe retracting springs return the brake shoes to their normal or released position. The return movement of the brake shoes, in turn, causes movement of the wheel cylinder pistons toward their released position, since the force from the master cylinder is removed. The displaced fluid returns to the reservoir.

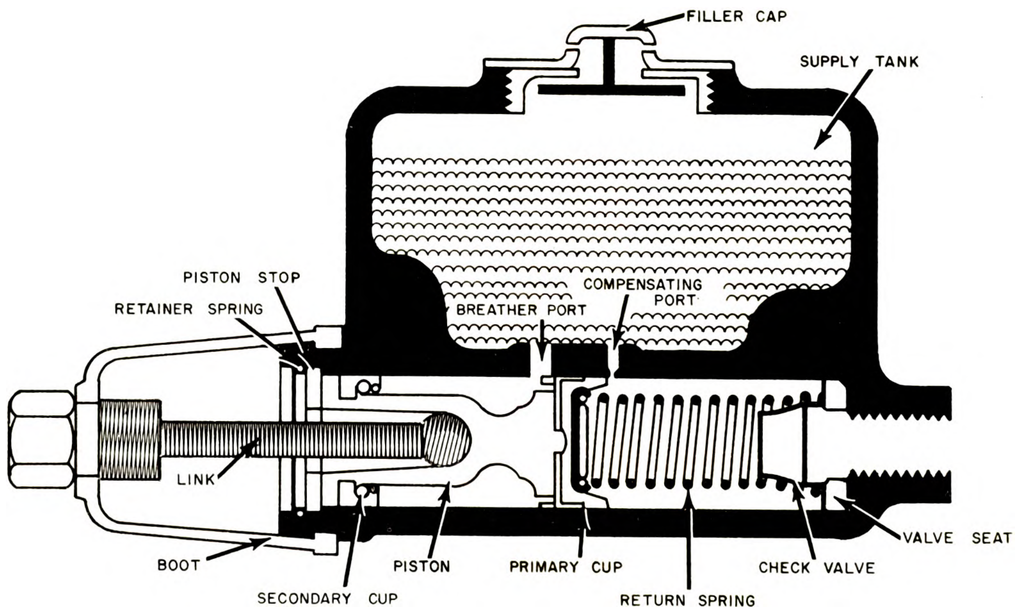
MASTER CYLINDER.—A cutaway view of a typical master cylinder is shown in figure 15-16. The unit consists basically of an iron casting containing a reservoir for the fluid and a machine finished precision cylinder which houses the piston, return spring, and two-way valve assembly.

There are two ports leading from the reservoir to the cylinder—the breather port and the compensating port. Both ports serve to furnish fluid to the cylinder for the braking stroke. In addition, the breather port allows the fluid on the rod side of the piston to escape to the reservoir during the release stroke. This prevents a fluid lock when the brakes are released. The compensating port allows fluid to flow to and from the reservoir to allow for thermal expansion and contraction. Thus, a constant volume is maintained in the system at all times.

The reservoir is sealed at the top with a combination filler and breather cap which permits atmospheric pressure on the fluid at all times.

The piston is a spool-like member with a rubber or leather cup seal at either end. These seals are referred to as the primary and secondary cups. The primary cup is held against the piston by the return spring and acts against the brake fluid during the braking stroke. The secondary cup is located at the other end of the piston and prevents external leakage of the brake fluid.

An explanation of the two-way valve can be made with reference to the illustrations in figure 15-17. As pressure is applied to the foot pedal and the piston forced into the cylinder, the fluid pressure is applied to the inner and outer segments of the two-way valve. The spring acting against the inner segment is comparatively light. As the fluid pressure opens this valve, additional fluid enters the hydraulic lines, applying pressure to the pistons in the wheel cylinders.



AS.748

Figure 15-16.—Hydraulic brake master cylinder.

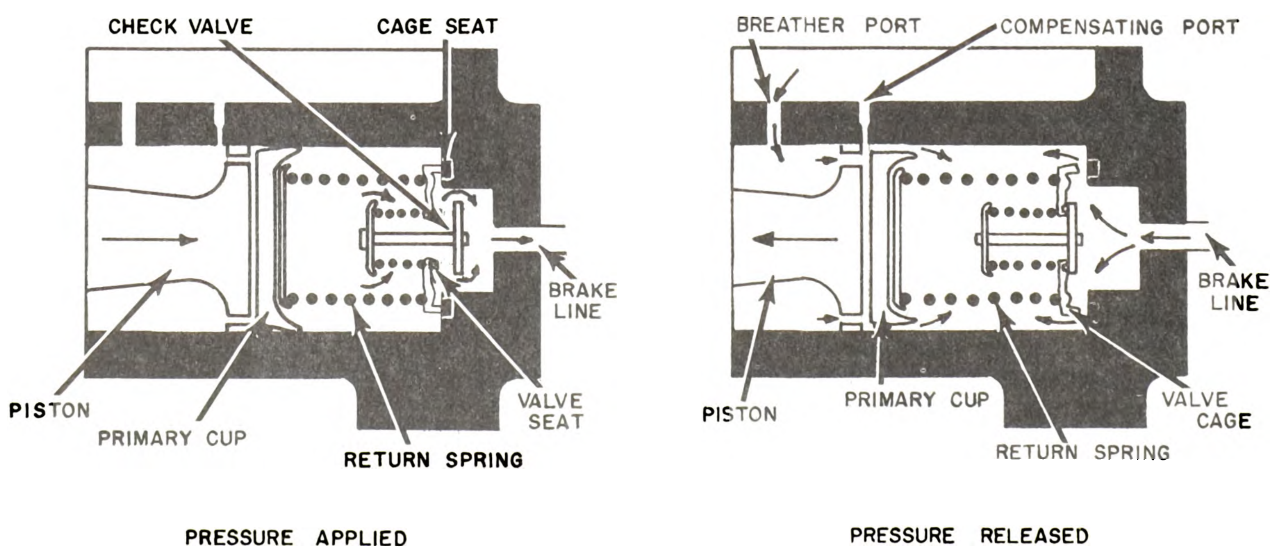


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Figure 15-17.—Hydraulic brake master cylinder—operation of two-way valve.

As the brake pedal is released, fluid pressure in the wheel cylinders decreases. The brake shoe retracting springs, acting against the wheel cylinder pistons, cause a slight back pressure in the fluid lines. This pressure overcomes the tension of the return spring and forces the entire two-way valve assembly off its seat. This allows some of the fluid from the lines to enter the reservoir.

When the pressure in the lines decreases to approximately 6 to 16 psi, the return spring closes the valve unit against its seat. As a result the system remains under a small pressure. This pressure will not cause the shoes to drag, but will assure a positive seal at the wheel cylinder cup packings and prevent air from entering the system.

WHEEL CYLINDER.—The wheel cylinder may be of almost any design or exterior shape to suit the need, but all wheel cylinders work on the same basic principle and fulfill the requirements of moving the brake shoes into contact with the drum. There are two basic designs, a single piston type and a double piston type, sometimes called uniservo and duoservo cylinder, respectively. Different combinations of these two types of cylinders are used on different models of equipment.

Figure 15-18 illustrates a double piston wheel cylinder. The single piston would be similar, only small because of one piston. This unit, regardless of whether single or double piston type, changes the applied fluid pressure into mechanical force to move the brake shoes. The wheel cylinder housing, made from a casting, is bolted to the brake backing plate.

In this example, the two pistons in the cylinder move in opposite directions under hydraulic pressure. Through a short stem, the pistons push the shoes against the drum. These stems are connected directly to the shoes.

Rubber cup seals fit tightly in the cylinder bore against each piston to prevent the escape of fluid. Between the cups is a light spring to keep the cups in position against the pistons. The open ends of the cylinder are fitted with rubber boots to keep out foreign matter.

Brake fluid enters the cylinder from the brake line connection between the pistons. A bleeder port and valve is located at the top of the cylinder between the pistons. This provides a means for releasing air from the system.

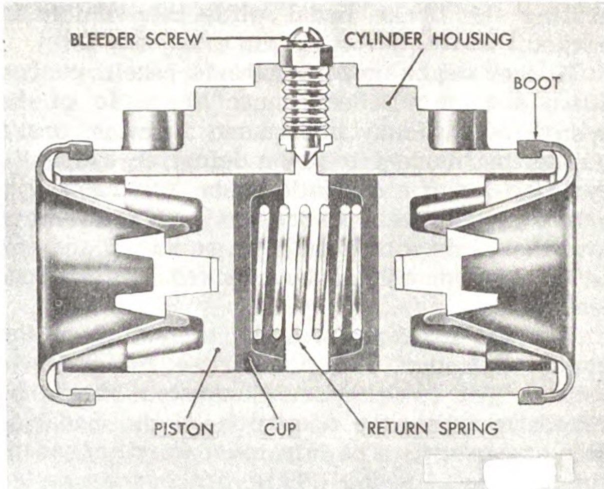

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Figure 15-18.—Hydraulic brake wheel cylinder.

Various applications of wheel cylinders are used in support equipment, depending upon the manufacturer's design. Some may have one single-piston cylinder or a dual-piston cylinder per wheel, each operating two shoes. Others may use a combination of one single and one dual or two dual-pistons per wheel. When a dual system is used, each cylinder is mounted diametrically opposite the other, and each operates one end of two shoes.

Inspection and Maintenance

Hydraulic brake systems must be inspected at specified intervals. A visual inspection includes checking the fluid level in the master cylinder reservoir, the security of mounting bolts and clamps, the condition of tubing and hose, and the entire system for leaks. When the wheels and drums are removed for inspection of the brake assemblies (discussed previously), the wheel cylinder should be inspected for leaks. The boots may be pulled from around the ends of the cylinder to check for leakage between the pistons and the cylinder wall.

An operational inspection of a hydraulic brake system may be accomplished during the road test previously described. However,

several checks may be accomplished by operating the brake pedal while the vehicle is parked.

If the brake pedal bottoms when pushed down, a further check must be made of the system. This may be caused by worn brake linings but more often by a defective hydraulic system. Insufficient fluid in the reservoir is a prime cause of this discrepancy. If the fluid is low, the reservoir should be serviced and the entire system should be checked for external leaks.

Internal leakage from the lines through the master cylinder will also cause the pedal to bottom. Air in the hydraulic system should be suspected when the operation of the pedal is soft or spongy. The air must be removed to obtain a solid pedal. This process is called bleeding and is covered later in this chapter.

The maintenance of hydraulic brake systems consists of correcting the discrepancies found during scheduled inspections and those which occur during normal operations. This includes servicing the system, repair and replacement of tubing and flexible hose, repair of the master cylinder and wheel cylinders, and bleeding the system. With the exception of the repair and replacement of tubing and flexible hose, which is covered in chapter 12, these maintenance items are described in the following paragraphs.

SERVICING.—As applied to hydraulic brake systems, servicing consists of adding necessary fluid to the master cylinder reservoir. When adding hydraulic fluid, be sure it is the kind recommended by the manufacturer. Some manufacturers use natural rubber seals in the operating systems, and others use synthetic rubber or other materials. Unless the recommended brake fluid is used, the seals deteriorate quickly, causing possible failure of the brake system.

Dirt and other foreign matter that accumulate around the filler opening can also affect brake operation. Even a small particle of dirt may find its way into the operating mechanism and close a vent or prevent a valve from sealing properly. All dirt and foreign matter must be removed before removing the filler cap. The fluid level should be approximately 1/4 to 1/2 inch from the filler opening. This information is usually specified in the applicable Service Instructions Manual. This space compensates for thermal expansion of the brake fluid.

MASTER CYLINDER REPAIR.—When the master cylinder requires repair, it must be removed from the vehicle. If a stoplight switch is mounted on the cylinder, the wires must be disconnected first. Next, the hydraulic line and the pedal linkage are disconnected from the cylinder. Then, loosen the holddown bolts and remove the cylinder. The exterior surface of the cylinder should be thoroughly cleaned before disassembly.

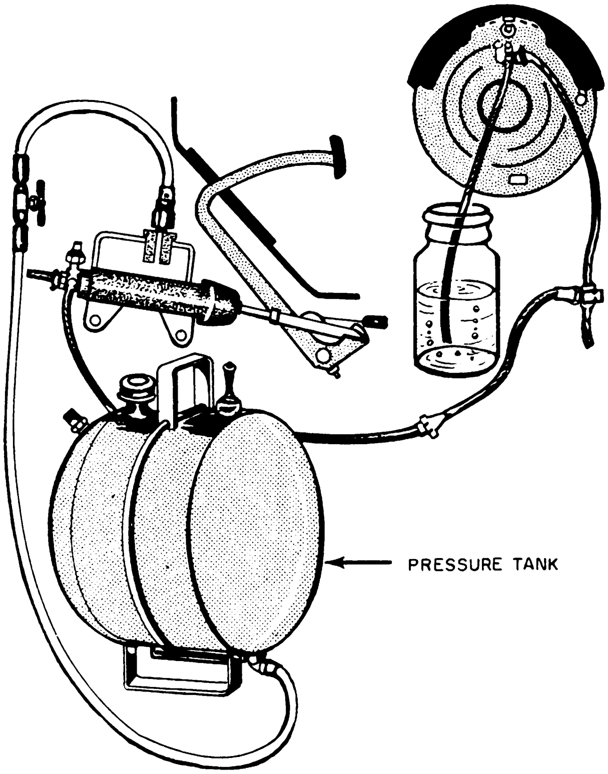
Figure 15-16 identifies the various components and parts referred to in the following disassembly, repair, and reassembly procedures.

After the exterior surface of the cylinder is cleaned, remove the fillercap of the reservoir and pour out and discard the fluid. Clamp the master cylinder, boot upward, in a vise and then remove the boot and pedal rod. Next, remove the retainer spring (snapring). With this removed, the piston stop (a thick steel washer) is free to be removed with the piston. Remove the master cylinder from the vise and up-end the cylinder to allow the piston, spring, and valve assembly to slide out. The secondary cup, primary cup, piston spring, and valve assembly should all be replaced with new parts. These items are usually available in a repair kit.

After the parts are removed, the cylinder walls should be cleaned and inspected. If there are deep pits or scratches in the bore, the master cylinder should be replaced. The cylinder bore may be honed with a suitable stone to remove rust, scores, and shallow pits and scratches. After honing a cylinder, be sure that all abrasive dust is removed; then lubricate the bore with new, clean brake fluid.

Assemble the parts into the cylinder in the logical order. First, install the valve assembly on the end of the piston return spring. Check again to insure that the bore of the cylinder is clean and is lubricated with clean fluid. Lubricate the new primary and secondary cups and piston. Guide the lips of the primary cup into the bore and use the piston to force the cup into the cylinder.

As the secondary cup is installed, be sure that the lips do not fold over when they contact the bore. Then place the piston stop on the piston, and with a drift punch inserted in the hole at the back of the piston, force the piston into place. Hold the piston in place and install the retainer spring. Replace the pedal rod and a new boot. Install the fillercap only after insuring that the venthole is open.



AS.751
Figure 15-19.—Bleeding hydraulic brake system—pressure method.

Reinstall the master cylinder on the vehicle, reconnecting the brake line and the wire to the stoplight switch. Then connect the pedal rod to the brake pedal. The applicable technical manual should be consulted for adjustment procedures of the pedal linkage. The master cylinder must be serviced and the system bled before the brakes are ready for service. However, before this is accomplished, all necessary repairs should be made to the wheel cylinders.

WHEEL CYLINDER REPAIR.—Wheel cylinders are rebuilt in much the same manner as a master cylinder. To accomplish this, it is seldom necessary to remove the cylinder assembly from the brake backing plate. However, before the cylinder can be repaired, the brake assemblies must be removed. This procedure was described previously in this chapter.

To disassemble a wheel cylinder with two pistons (fig. 15-18), pull the boots from the cylinder and push the pistons, cups, and spring out of the cylinder.

After the parts are removed, clean the cylinder wall and check for pits and accumulation of rust. A small quantity of pits or rust at the exact center of the cylinder will not affect the operation of the wheel cylinder. If the rust or pits are just inside the outermost polished areas of the cylinder bore, they must be removed by honing. Cylinders containing deep pits or scratches must be replaced.

After honing a cylinder, remove all the abrasive dust and lubricate the cylinder walls with clean, new hydraulic fluid. The pistons are usually composed of aluminum, and unless badly scored, they may be reused indefinitely. However, they should not be sanded; only cleaned with an approved solvent or clean hydraulic brake fluid.

After the cylinder bore is satisfactorily cleaned and lubricated, lubricate the cup seals. Insert the cup into that end of the cylinder in which it will function. Do not push the cup through the bore. As soon as the lips of the cup are in the bore, use the piston to move the cup in place.

Installing the other cup and piston may be more difficult, since the cup retaining spring will push against the cup and piston already installed. With one hand, hold the one piston from pushing out, and with the other hand, install the spring, cup, and piston. Then install the boots and brake shoe links, rods, or slugs. Install a wheel cylinder clamp or use a cord or wire to tie a loop around the cylinder to hold the components in the cylinder until the brake shoes are installed.

BLEEDING HYDRAULIC BRAKE SYSTEMS.—During repair of the master brake cylinder or wheel cylinders, or anytime a brake line is disconnected, air will enter the hydraulic brake system. Also, when the fluid level in the reservoir is allowed to become too low, air will enter the brake lines.

Most hydraulic systems are equipped with return lines between the actuating units and the reservoir. The fluid circulates from the reservoir, through the supply lines, through the actuating units, and back to the reservoir. This allows any air in the system to escape through the reservoir vent during circulations.

Brake hydraulic systems, however, are not equipped with return lines; therefore, there is no means for the air to escape. As previously stated, air in the system will cause the action

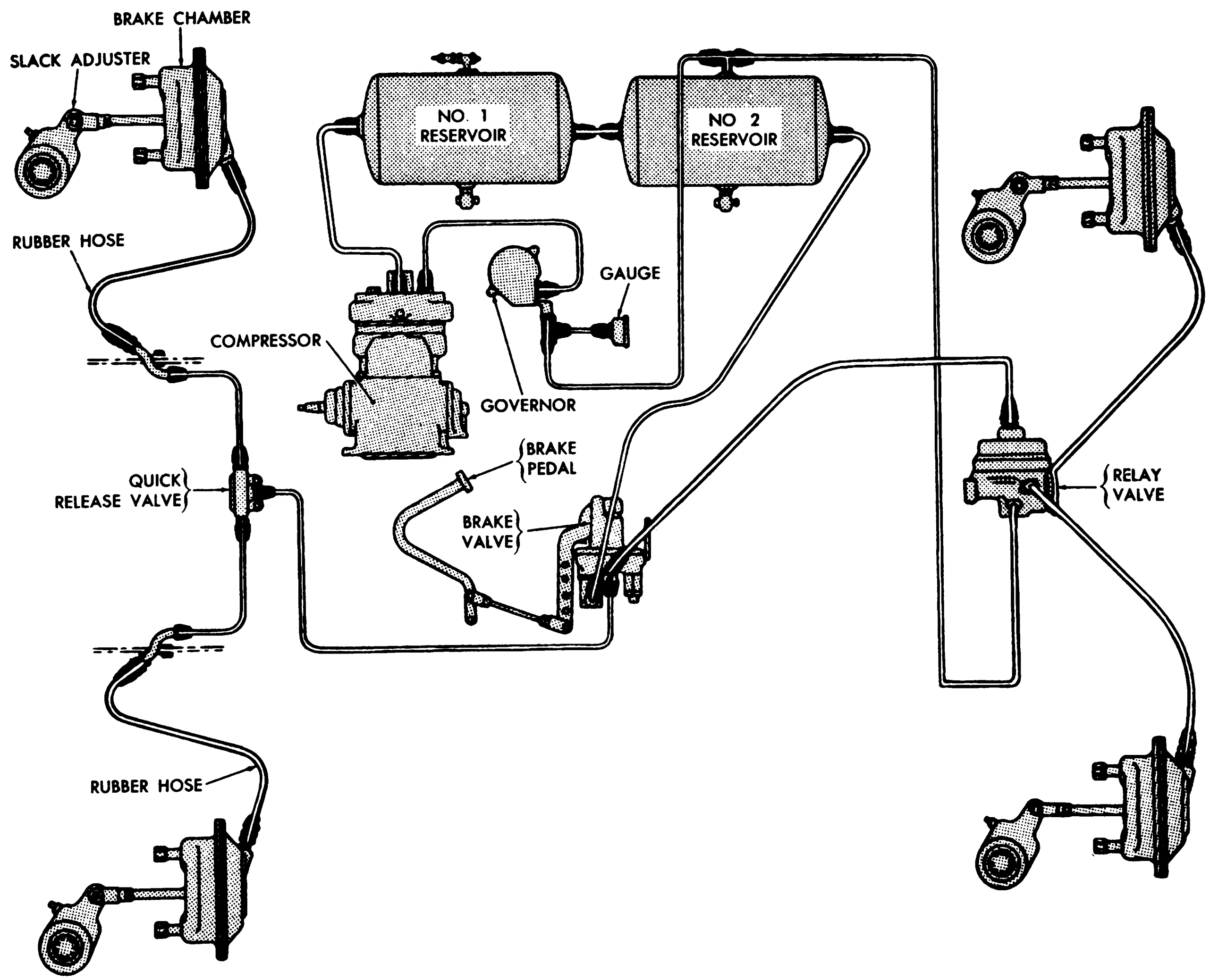


Figure 15-20.—Diagram of typical airbrake system.

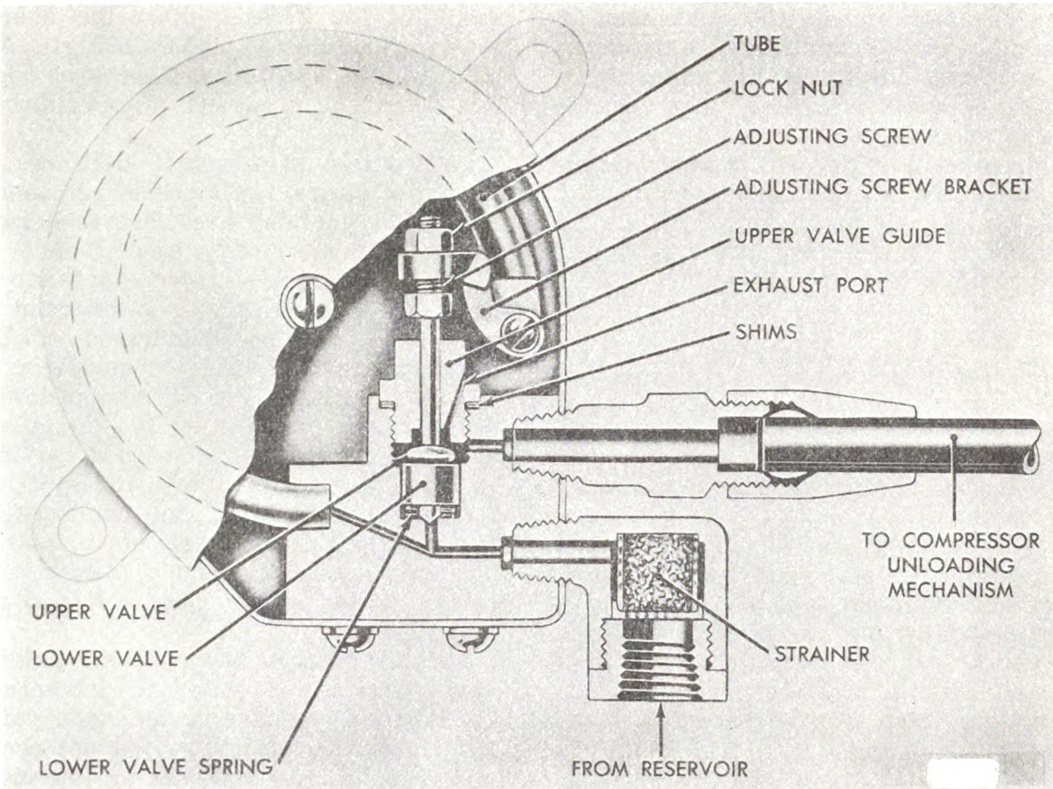
of the brake pedal to feel soft and spongy. This is because air is compressible. The hydraulic brake system must be bled to expel this air.

There are two common methods of bleeding a hydraulic brake system—the pressure method and the manual method. The pressure method employs a brake bleeder tank which delivers fluid under pressure to the master cylinder. (See fig. 15-19.)

The accepted procedure for use of the pressurized bleeder tank is (1) insure that the tank has an adequate supply of the required type brake fluid and (2) make sure that the valve on the discharge line is closed before the tank is pressurized. The normal operating pressure is approximately 25 psi.

Manufacturers usually recommend that the master cylinder reservoir be filled with hydraulic fluid before connecting the pressure tank. Make sure there is a tight seal between the adapter cap and the master cylinder filler port. Then apply pressure to the master cylinder by opening the valve on the discharge line of the tank.

Most authorities recommend that the system should be bled by starting with the longest



AS.753

Figure 15-21.—Sectional view of governor for an airbrake system.

line and working successively to the shortest. Other authorities prefer the opposite method; that is, by starting with the shortest line and finishing with the longest. Therefore, the recommended procedure listed in the applicable Instructions Manual should be followed. If it is suspected that the air is entrapped in one specific brake line, that line should be bled first. For example, assume that the right rear wheel cylinder of a vehicle has been disconnected for maintenance and repair. After the repair has been completed and the cylinder connected, this brake line should be bled first. In fact, it is possible that all of the air which entered the line while it was disconnected may be bled from the one bleeder valve.

If at all possible, use a length of flexible tubing and a clean glass bottle or jar to trap the brake fluid expelled from the wheel cylinder bleeder valve. Before attaching the tube, be sure to clean the bleeder valve end.

Loosen the bleeder valve screw. This allows fluid to flow into the jar. Keep the end of the tube submerged in the fluid. By observing the flow from the tube, air bubbles will appear. When the air bubbles stop, all the air has been expelled from that section of line and the wheel cylinder. Then tighten the bleeder valve screw. Repeat this procedure with each bleeder valve. The use of the tube and jar is recommended regardless of the method used to force fluid through the lines.

The manual method requires two persons. One man operates the brake pedal, pumping until the pedal action is hard—hydraulic pressure in the system. The other man opens the bleeder valve screw, allowing the air and fluid to escape as the brake pedal is still forced

downward. As soon as the brake pedal nears bottom, the operator signals the other man so that he can close the bleeder valve. As soon as the valve is closed, the brake line pressure is again pumped up and the bleeder valve opened, repeating the process until the air is expelled.

When bleeding a hydraulic brake system that consists of two wheel cylinders, an upper and lower on each wheel, the operation is slightly different. In that case, bleed the upper cylinder at each wheel first, then the lower cylinder.

PNEUMATIC BRAKE SYSTEMS

Pneumatic brake systems, commonly referred to as airbrakes, were developed to enable the operator to apply sufficient braking action to wheels of high-speed, heavily loaded vehicles. Direct physical effort or push on a lever or pedal is limited. With modern airbrake systems, the brake pedal is merely a controlling device for the breaking force, which is compressed air. On a vehicle that tows trailers provided with airbrakes, an additional hand controller, which may be operated separately or in conjunction with the pedal, is provided.

Application

Although the use of pneumatic brake systems is limited to a few items of heavy support equipment, the ASH is responsible for their maintenance and repair. Therefore, he must know the operation of the system, the location of the individual units, and the particular adjustments required.

Components and Operation

In an airbrake system, an engine-driven air pump or compressor is used to compress air and force it into a reservoir, where it is stored under pressure and made available for operating the brakes. Air under pressure in the reservoir is released to the brake lines by an air valve operated by the brake pedal. This released air goes to the brake chambers located near the wheel brakes.

Each brake chamber contains a flexible diaphragm and a plate. The force of the compressed air admitted to the chamber causes the diaphragm to move the plate, and this action, in turn, operates the brake shoes through a mechanical linkage. Considerable force is available for braking since the operating air pressure may be as high as 100 psi. All brakes on a vehicle, and on a trailer when one is used, are operated by means of special regulating valves.

A diagram of a typical airbrake system is shown in figure 15-20. The fundamental units and their functions are described individually in the following paragraphs.

COMPRESSOR.—The compressor is generally a single-acting reciprocating unit. It may be either self-lubricated or lubricated from the vehicle engine lubricating system. The compressor may be equipped with either water-cooled or air-cooled cylinder heads. The compressor is connected to the engine either through pulleys or a direct drive. When the engine is running, the compressor pumps air into the reservoir of the airbrake system. The two pistons can pump from 8 to 12 cubic feet of air per minute when driven at a speed of 1,250 rpm.

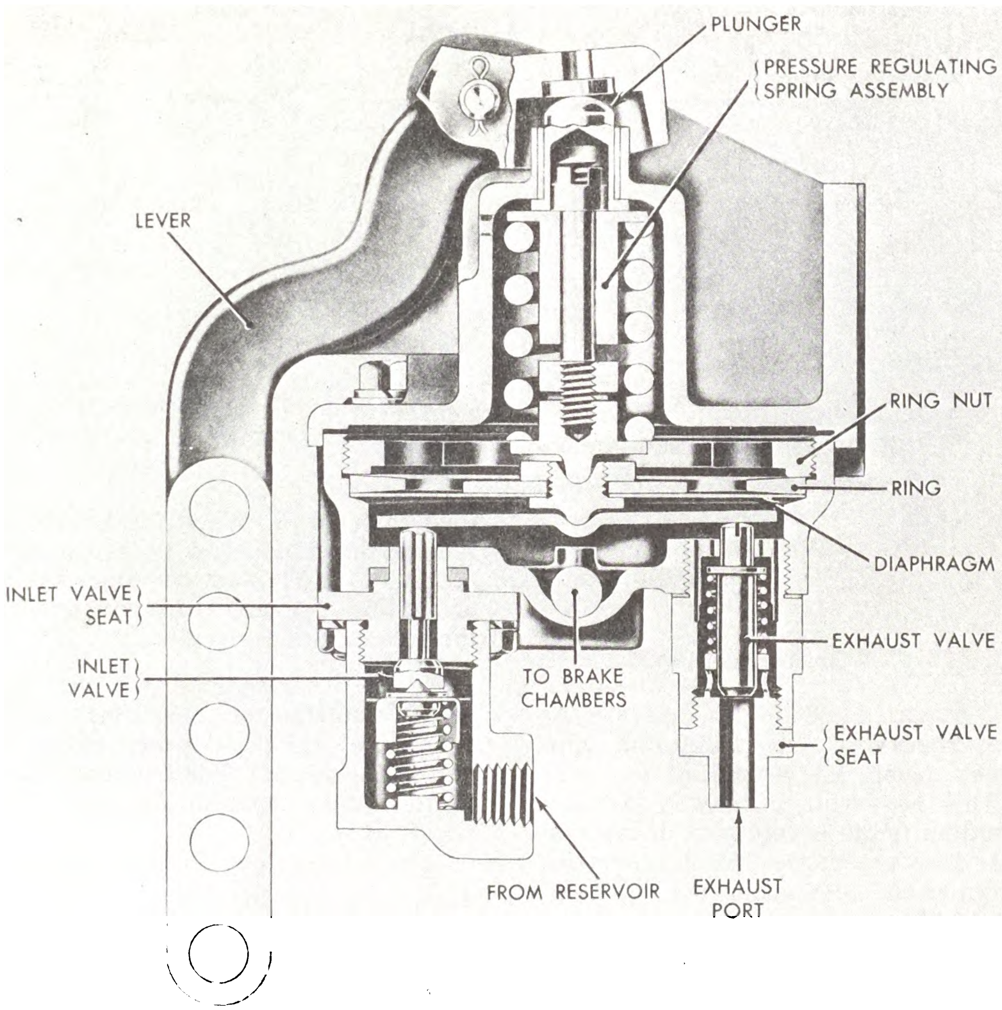
An air cleaner at the intake ports permits only clean air to enter the compressor. At each discharge valve, an unloader valve (separate from the discharge valves) prevents the compressor from building up too much pressure in the reservoir.

When the air in the reservoir is compressed to a preset pressure, the unloader valves are opened by the action on the governor, permitting the compressor to operate without compressing air. On some compressors the inlet valve is operated by the unloader mechanism.

GOVERNOR.—The governor, connected between the unloader head of the compressor and the reservoir, limits the reservoir pressure to a predetermined range. In normal operation, the upper limit is approximately 105 psi and the lower limit approximately 85 psi.

The operation of the governor is based on a flexible tube like that used in a pressure gage. The sectional view of the governor in figure 15-21 shows the operation when air is being compressed. The reservoir pressure is below the upper limit, and the tension exerted by the tube through the bracket and valve stem holds the lower valve seated. When the lower valve is seated, no air can escape from the reservoir, and the compressor builds up the required pressure.

When the pressure in the reservoir reaches the upper limit, the force of the air pressure overcomes the tension of the flexible tube so



AS.754

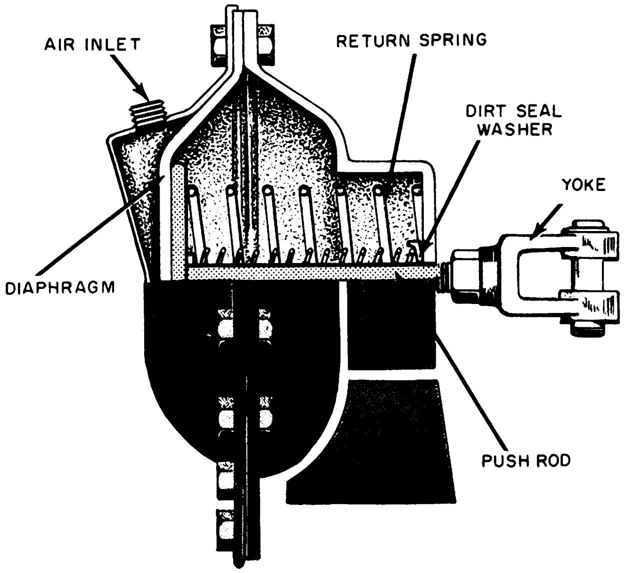
Figure 15-22.—Airbrake valve.

that the lower valve unseats and the upper valve is seated. This action forces the unloader valves in the compressor to open, permitting the compressor to operate without compressing air.

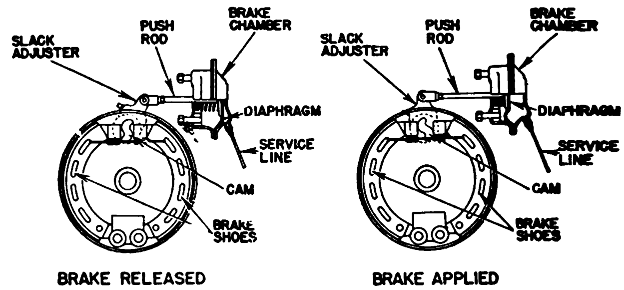
When the reservoir pressure drops to the low limit, the governor tube returns to the original position and permits the compressor to again pump air into the reservoir.

AIR PRESSURE GAGE.—An air pressure gage indicates whether the compressor and the governor are operating properly. This gage may be found on the instrument panel of some vehicles, or near the governor on others. In any case, it is located in the air line between the compressor and the reservoir.

AIR RESERVOIR.—The air reservoirs—usually two of them as shown in figure 15-20—are built of steel to withstand higher pressures than are normally required to operate the brakes. In addition, each reservoir is provided with a safety device (valve) which will open when the pressure exceeds approximately 150 psi. To prevent the possibility of rust or corrosion, each reservoir is also painted inside and out and has a drain valve to remove water.



AS.755
Figure 15-23.—Brake chamber.



AS.756
Figure 15-24.—Operation of brake shoes from brake chamber.

The No. 1 reservoir, into which the compressor forces fresh air, is called the WET reservoir. This reservoir is usually mounted so that the bottom is the lowest part of the system. The air then enters the No. 2 reservoir, which is known as the DRY reservoir. Although each tank should be drained daily, more water from condensation will settle in the No. 1 reservoir. Air for operating the brakes is taken from the No. 2 reservoir to reduce the possibility of moisture accumulating in any of the operating units where it might freeze or cause corrosion.

BRAKE APPLICATION VALVE.—The brake application valve, operated by the foot pedal, controls the application of the airbrakes. When only a little braking effort is required, the operator depresses the pedal only slightly. For full braking effort, the brake pedal is depressed all the way.

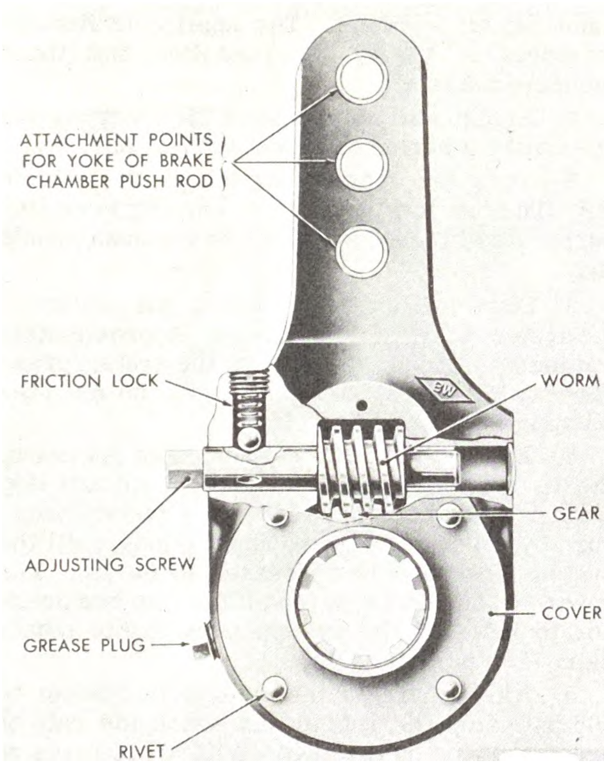
Depressing the brake pedal pulls the brake valve lever (fig. 15-22), which in turn moves a diaphragm within the brake valve housing. Movement of the diaphragm opens the intake valve and allows air from the reservoir to reach the brake chambers of the individual brakes. The downward movement of the diaphragm also closes the exhaust valve leading to the atmosphere. When the brake pedal is released, the diaphragm is forced upward by the trapped air. This action closes the intake valve and allows the air to escape from the system through the exhaust valve.

In an intermediate position of the brake pedal, a balance of pressure is established between the upper and lower sides of the brake valve diaphragm. This balance will hold the air in the brake system for the braking effort required.

RELAY VALVE.—A relay valve is used on some long wheelbase vehicles to speed up the application and release of the airbrakes. Air pressure to operate brake chambers controlled by the relay valve comes directly from the reservoir and can leave the system through an exhaust valve in the relay unit.

When the brake pedal is depressed, a diaphragm in the relay valve is actuated from the brake valve. This allows air to flow directly from the reservoir through the relay valve and to the brakes. Thus, brakes controlled by the relay valve are applied and released as quickly as those closer to the brake valve.

BRAKE CHAMBERS.—The brake chambers (fig. 15-23) which operate the brake shoes of rear wheel brakes are mounted on the rear axle. Front wheel brake chambers are usually mounted on the backing plate of the wheel brake assembly. When the brakes are applied, air pressure entering the brake chamber through the service lines exerts a pressure on the diaphragm and forces the push rod to move and operate the brake shoes.

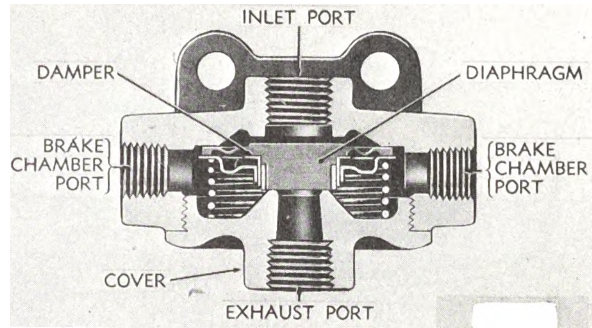


AS.757
Figure 15-25.—Slack adjuster.

The brake chamber push rod is attached to the slack adjuster arm. (See fig. 15-24.) During brake operation, the entire slack adjuster rotates with the brake camshaft, which expands the brake shoes by cam action.

SLACK ADJUSTERS.—Slack adjusters function as adjustable levers and provide a means of adjusting to compensate for wear of brake linings. For brake adjustment, turning of the worm (fig. 15-25) causes the slack adjuster to move (walk) around the gear, which is splined to the brake camshaft, thereby changing the position of the lever arm with respect to the brake camshaft. The slack adjuster provides a quick and easy means of adjusting airbrakes.

QUICK RELEASE VALVE.—The quick release valve is provided to reduce the time required to release the brakes by hastening the exhaust of air under pressure from the brake chambers.



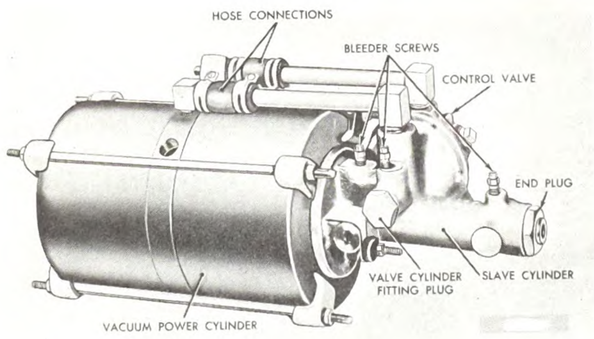
AS.758
Figure 15-26.—Quick release valve.

The valve contains a spring-loaded diaphragm so arranged as to permit airflow through the valve in only one direction. In the brake application position, air under pressure from the brake valve enters the inlet port. (See fig. 15-26.) The diaphragm is forced downward and closes the exhaust port. The air pressure then deflects the outer edges of the diaphragm downward and enters the brake chambers to apply the brakes.

As soon as the air pressure in the chambers and below the diaphragm equals the air pressure above the diaphragm, the diaphragm spring forces the outer edge of the diaphragm up against the valve body. This action closes off the brake chambers from the inlet port. In this holding position, the diaphragm continues to retain the exhaust valve in the closed position. If the pressure above the diaphragm is reduced or completely released by the operator releasing the brake pedal partially or completely, the air pressure below the diaphragm causes the diaphragm to be raised to open the exhaust port and release the brake chamber air pressure.

Inspection and Maintenance

The inspection of pneumatic brake systems is similar to that of other brake systems. Both visual and operational inspections must be conducted at specified intervals. The air line hoses and couplings should be checked for leaks and wear. Worn hoses must be replaced and loose connections and couplings tightened. The drain valve at each reservoir should operate freely and be drained daily. A small amount of



AS.759

Figure 15-27.—Hydrovac vacuum power brake cylinder.

penetrating oil will free a binding drain valve. The air strainer on the compressor should be cleaned and then saturated with a medium grade oil periodically.

Some compressors receive their lubrication from the engine; others have a self-contained lubricating system which should be checked daily, and to which oil must be added when required. The oil should be drained each time the engine oil is drained and refilled with the proper grade of oil specified in the appropriate instructions manual.

Slack adjusters should be lubricated by removing the lubricating plug and filling the small gear cavity with the approved lubricant at the intervals specified in the applicable technical manual. Do not force excessive lubricant into the cavity as it may reach the brake linings.

As previously stated, the slack adjusters provide the means for adjusting pneumatic brakes. Referring to figure 15-25, note the adjusting screw. On some slack adjusters, the adjusting screw is equipped with a locknut. For adjustment, loosen the locknut and turn the adjusting screw tight. This rotates the worm gear, taking up the slack in the camshaft. Back off the adjusting screw approximately one-sixth turn and tighten the locknut. This adjustment can be made quickly at each wheel brake without hoisting the vehicle. However, if the play in the brake linkage is excessive, the wheel and brake drum should be removed to inspect the lining.

The following is a typical system check for a pneumatic brake system. The pressure and time measurements indicated may not be the same for all systems. The applicable Service Instructions should be consulted for these measurements.

1. Deplete all compressed air from the air system by a series of brake applications.

2. Turn the ignition switch of the vehicle ON. The low level pressure warning lamp (incorporated in most systems) on the dash should light.

3. Start the engine to check the ability of the system to build up pressure. Approximately 5 minutes is required to raise the system pressure from 50 psi to 90 psi. At 60 psi, the warning light should go off.

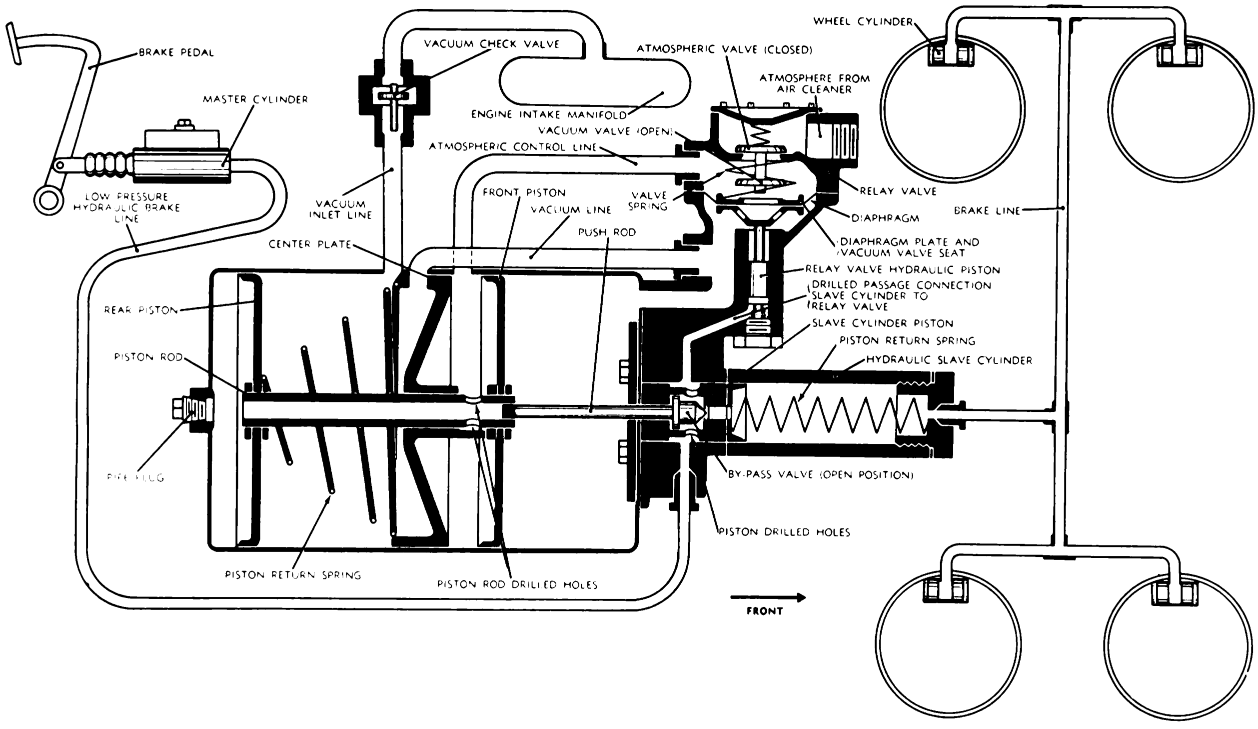
4. At 100 psi to 105 psi indicated pressure, the air system governor should cut out and stop further compression. Reduce the system pressure by a series of brake applications until the system pressure is decreased to 80 psi. The governor should cut in and allow the compressor to build up the system pressure to maximum—100 psi to 105 psi.

5. After charging the system to 100 psi to 105 psi, stop the engine and watch the rate of pressure drop on the gage. With all controls of the system in the released position, the system should not lose more than 2 pounds pressure per minute. When the brakes are fully applied, the pressure drop should not exceed 3 pounds per minute. If the pressure drop in either leakage test is excessive, check for air leaks throughout the system and repair as necessary.

For major maintenance and repair of pneumatic brake systems, the applicable technical manual should be consulted.

POWER BRAKE SYSTEMS

As previously stated, the brake system most commonly used on powered support equipment is the hydraulically operated system. However, the increase in size and weight of aircraft has required heavier and more powerful support equipment, especially the aircraft towing tractors. With this increase in vehicle power and weight, it became necessary to have a brake system that was more effective and less strenuous for the operator. It became almost impossible for the operator to apply sufficient braking action to control a heavy, yet comparatively small, vehicle. To compensate for this, some hydraulic brake systems are equipped with a



AS.760

Figure 15-28.—Hydrovac operation—released position.

form of power system to assist the force of the operator's foot in applying the brakes.

Power brake systems use the principle of the hydraulic brake to operate the wheel brake cylinders and produce braking action. In addition, these systems utilize the energy of air pressure, either to apply the necessary pressure to the hydraulic fluid or to assist in this application. Atmospheric pressure provides this energy in some power systems, while a compressor is required in others.

Application

Many of the Navy's aircraft towing tractors are equipped with some type of power brake system. Some are equipped with a form of vacuum-boost system while others utilize an air-over-hydraulic system. These two types of power systems are described in the following paragraphs.

Vacuum Systems

As explained in Fluid Power, air has weight and this weight results in a pressure (atmospheric pressure) of approximately 14.7 psi at sea level. It is this pressure that is used in the operation of vacuum brake systems.

It is impossible to create a perfect vacuum, but by pumping air from a container it is possible to obtain a difference in pressure between the outside and the inside of the container. This creates a partial vacuum within the container. If the container were suddenly opened, outside air (atmospheric pressure) would rush into the container to equalize the pressure. It is upon this principle that the power cylinder of a vacuum brake system operates.

There are many varieties of vacuum powered brake systems and it is impossible to cover them all within the scope of this training manual. The system most commonly used on ground support equipment is a one-unit type

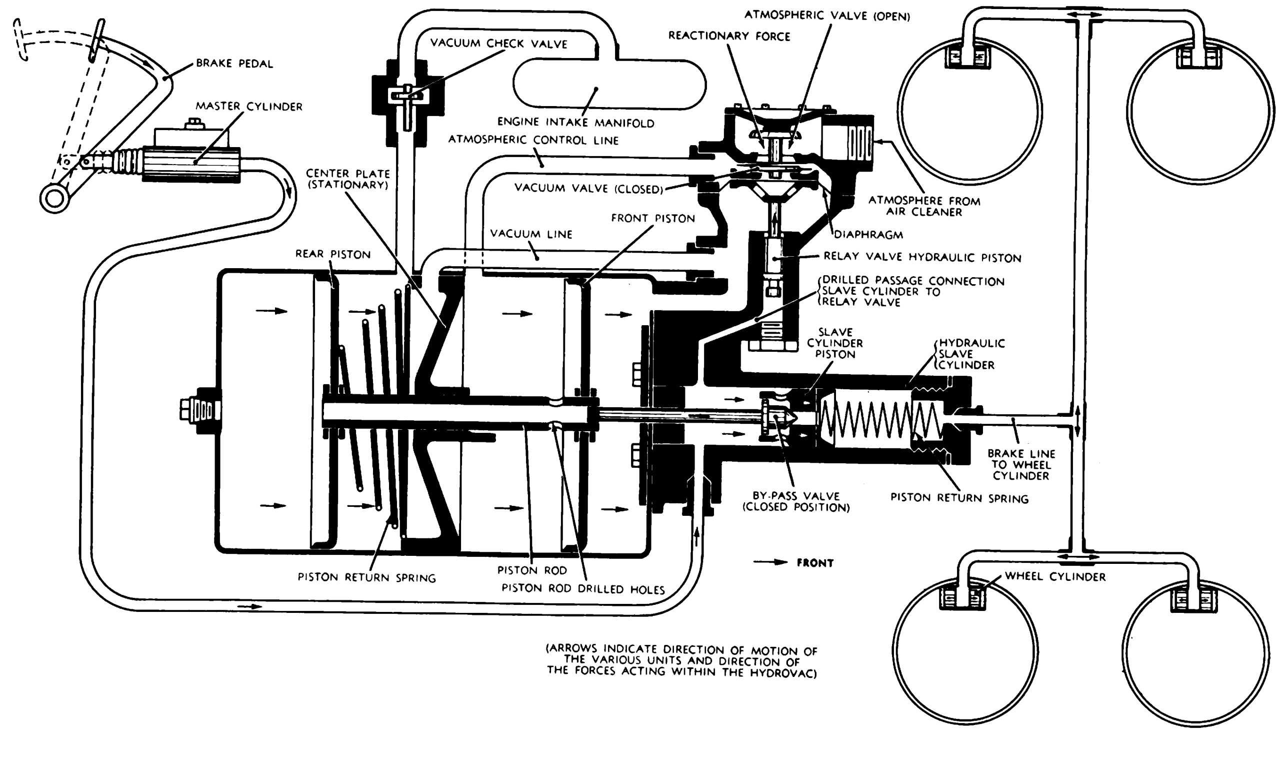


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Figure 15-29.—Hydrovac operation—applied position.

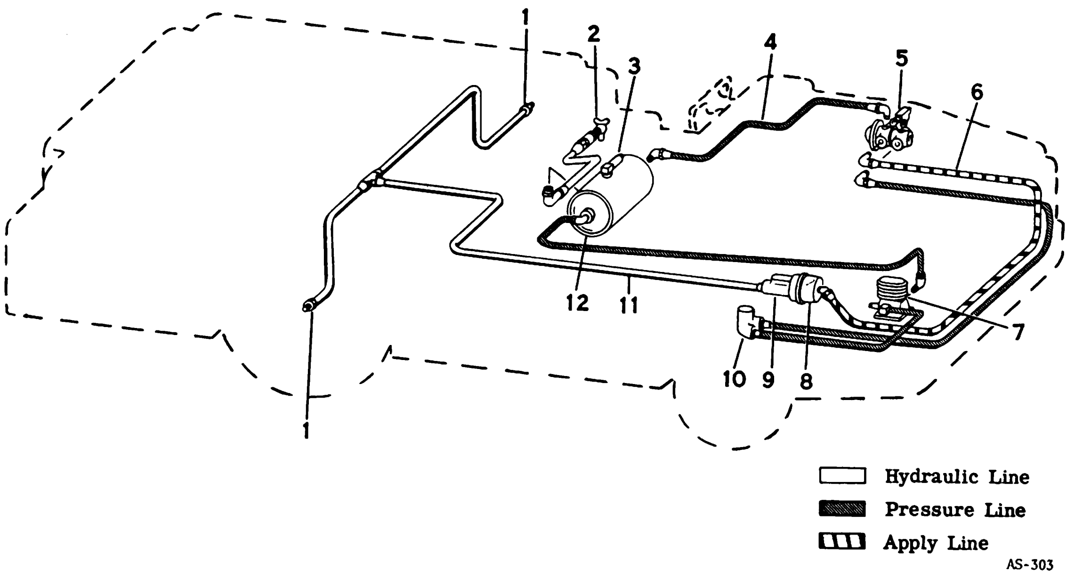
referred to by the trade name, Hydrovac. Therefore, the operation of this unit is described in the following paragraphs.

The Hydrovac combines into one assembly (fig. 15-27) a hydraulically actuated control valve, a tandem piston vacuum power cylinder, and a hydraulic slave cylinder. The vacuum power brake cylinder is connected hydraulically to both the master cylinder and the wheel cylinders.

The vacuum source for this system, as for all vacuum brake systems, is the intake manifold of the engine. A check valve maintains a vacuum within the system, even after the engine is stopped, by closing the intake manifold when the pressure in the manifold rises above the vacuum pressure within the system. A vacuum reservoir is usually required so that a substantial source of vacuum is available. Once air is pumped out of the vacuum reservoir through the intake manifold, the resulting vacuum is diminished only by operating the power cylinder.

The vacuum power cylinder is divided into four compartments by the front and rear pistons and the center plate. (See fig. 15-28.) The vacuum source is directly connected to the compartment between the center plate and rear piston. The vacuum is connected from this compartment, by means of the vacuum line, to the relay or control valve. From the control valve, the vacuum is connected to the front compartment by a passage in the valve body.

In the released position, the control valve diaphragm plate and vacuum valve seat is held down by the valve spring. This keeps the vacuum valve open and the atmospheric valve closed. In this position, the vacuum is connected through the vacuum valve and the atmospheric control line to the compartment between the center plate and front piston and, through the ports in the hollow piston rod, to the rear compartment. Vacuum is therefore present in all compartments in the released position and both pistons remain inoperative.



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1. Wheel cylinder connectors.
2. Tank drain valve.
3. System safety valve.
4. Compressed air line.
5. Control valve.
6. Control air line.
7. Air compressor.
8. Air chamber.
9. Master brake cylinder.
10. System governor.
11. Hydraulic line.
12. Air reservoir.

Figure 15-30.—Air-over-hydraulic brake system.

The piston return spring holds the pistons in the **OFF** position. The push rod, in the released position, maintains the bypass (check) valve off its seat, permitting a direct hydraulic connection from the master cylinder, through the hydraulic slave cylinder, to the wheel cylinders.

With this construction, foot pedal pressure can be applied to the wheel cylinders for braking action should vacuum or Hydrovac failure make the power cylinder inoperative. The relay valve diaphragm has vacuum on both sides and is held in the **OFF** position by the valve spring. When the vacuum in the Hydrovac is the same as, or greater than, the source vacuum, the poppet valve in the vacuum check valve rests on its seat and, in the event of engine failure or rapid acceleration, traps the vacuum in the Hydrovac system in readiness for brake application.

As the foot pedal is depressed, fluid is forced from the master cylinder through the open bypass (check) valve to the slave cylinder and on to the wheel cylinders. (See fig. 15-29.) The fluid is also forced through the drilled bypass passage to the relay valve hydraulic piston, which is forced outward against the pressure of the valve spring. This gradually forces the diaphragm plate and vacuum valve seat toward the applied position.

The movement of the diaphragm first closes the vacuum valve against its seat, sealing off the vacuum from the atmospheric control line. After the vacuum valve is seated, further motion of the diaphragm causes the atmospheric valve to leave its seat. This permits air from the air cleaner to enter the atmospheric control line, then to the compartment between the center plate and the front piston. It then flows through the hollow piston rod to the rear compartment. With the vacuum still present on the front side of both pistons and atmospheric pressure on the rear sides of both pistons, the pistons are forced toward the slave cylinder.

Movement of the pistons and push rod toward the slave cylinder closes the bypass (check) valve, and then causes the slave-cylinder piston to move outward. This forces fluid under pressure into the wheel cylinders to apply

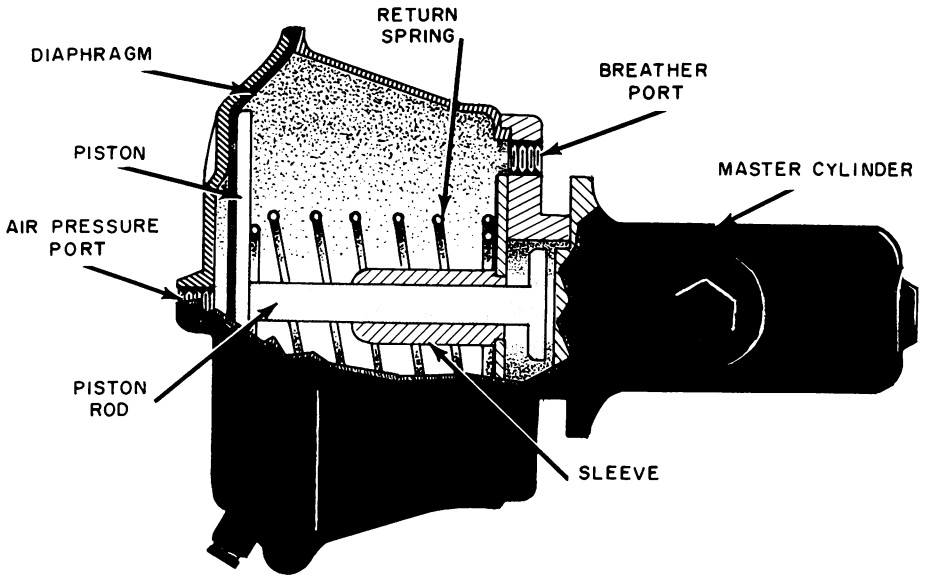

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Figure 15-31.—Master cylinder assembly—air-over-hydraulic brake system.

the brakes. The foot-pedal pressure, acting through the master cylinder, also acts against the slave-cylinder piston, assisting the vacuum pistons and push rods. The pressure at the wheel cylinders (that is, the total braking effort) is the sum of the output of the vacuum pistons in the Hydrovac and the foot-pedal pressure at the master cylinder.

Release of foot-pedal pressure removes the fluid pressure from below the relay valve hydraulic piston. This allows the valve spring in the relay or control valve to return the atmospheric and vacuum valves to the released position. The atmosphere is exhausted from the rear sides of both pistons, making them inoperative and allowing the piston return spring to move the pistons to the released position.

When the foot pedal movement stops at some intermediate point between the released and fully applied position, the pistons will move slightly toward the applied position. This reduces the fluid pressure under the relay valve hydraulic piston the necessary amount to allow the diaphragm to drop and close both the atmospheric and vacuum valves in the control valve. Thereafter, the slightest foot-pedal movement, either toward the released or applied position, will result in the opening of either the vacuum or atmospheric valve, and will partially release or further apply the brakes.

INSPECTION AND MAINTENANCE.—With the exception of the vacuum system and particularly the power cylinder, the inspection and maintenance procedures for vacuum brake systems are similar to those required for hydraulic brake systems.

To check the vacuum brake system, first shut off the engine and apply the brakes several times to bleed all vacuum from the system. This may require as many as 20 or 30 applications on systems equipped with vacuum reservoirs. Spongy or soft action of the brake pedal indicates air in the hydraulic system. If this occurs, the system must be bled. The bleeding procedure is discussed later.

With the pedal held at the normal braking pressure, start the engine. If the pedal lowers toward the floorboard when the engine starts, the vacuum system is operating properly. If the pedal fails to move, the vacuum system is at fault. Although this usually indicates a faulty vacuum cylinder, the vacuum lines, reservoir, and connections should be checked for leaks first. The applicable instructions manual should be consulted for the replacement and repair of the vacuum power cylinder.

The procedure for bleeding the system is very similar to that required for hydraulic brake systems, previously described. When bleeding the system, be sure to maintain a full supply of brake fluid in the master cylinder. Make certain the brakes are fully released. If the vehicle has been operated recently, make enough applications with the brake pedal to destroy any vacuum that might be in the vacuum cylinder.

Bleed the air from the Hydrovac unit first, using either the pressure or manual method previously described. Start with the bleeder port nearest the vacuum cylinder and work to the bleeder port nearest the end of the slave cylinder. (See fig. 15-27.) After the Hydrovac unit is free of air, bleed each wheel cylinder.

Air-Over-Hydraulic Systems

Like vacuum systems, there are several different types of air-over-hydraulic power systems. One type operates similar to the Hydrovac unit. The main differences are that compressed air, furnished by a small compressor driven by the engine, does the same work as the atmospheric pressure does in the Hydrovac, and atmospheric pressure the same work as the vacuum.

Figure 15-30 shows a type of air-over-hydraulic brake system that is used on some of the newer tow tractors. Note that the pneumatic portion of this system is similar to the pneumatic brake system previously described. The components—compressors, reservoir (tank), governor, and air control valve—are similar in design and operation to the components of the pneumatic brake system. The air control valve is similar to the brake application valve in the pneumatic system; however, it controls the flow of compressed air to an air chamber in the master cylinder, rather than directly to the air chamber in the pneumatic system. The air control valve is mechanically linked to the brake pedal.

Brake application is relative to the pressure applied by the operator on the brake pedal. The brakes of the vehicle may be partially released at any time by slightly relieving pressure on the pedal or entirely released by removing all pressure from the pedal. One of the ports of the air control valve is an exhaust port which releases air from the air chamber of the master cylinder during the release action.

The master brake cylinder assembly is the point in this system where the pneumatic system and hydraulic system join. Figure 15-31 depicts a partial cutaway view of the assembly. Only the air chamber is shown cutaway because the design and operation of the master cylinder part of the assembly are similar to any other hydraulic master brake cylinder.

The piston and piston rod of the air chamber is connected to the push rod of the master cylinder. When the brakes are applied, the air control valve allows air under pressure to enter the air pressure port of the air chamber. This pressure forces the diaphragm to move the piston and piston rod in the air chamber and compresses the return spring. This movement, in turn, moves the push rod and piston in the master cylinder forcing fluid pressure to the wheel cylinders. When the brakes are released, the air control valve stops the flow of air to the air chamber and at the same time opens the exhaust port. This allows the air to flow out of the chamber, through the line, and out the exhaust port of the control valve. The return spring returns the piston and piston rod to the release position. This movement releases the brakes through the action of the master cylinder.

INSPECTION AND MAINTENANCE.—The inspection and maintenance procedures (described previously) for hydraulic and pneumatic brake systems apply, respectively, to the hydraulic and pneumatic portions of the air-over-hydraulic system. The appropriate technical manual should be consulted for required maintenance of the master cylinder assembly.

CHAPTER 16

POWER TRAIN AND STEERING SYSTEMS

The power train serves as a link to transmit the power developed by the engine to the drive wheels of self-propelled support equipment. Since the ASM is responsible for the engine and the ASH is responsible for the axles, wheels, and brakes, the power train also serves as a link between the two service ratings. Although the ASM is assigned the overall responsibility for the power train and steering systems, there are certain requirements in these areas that are common to both the ASM and ASH. Both service ratings must know the functions of the components of the power train, suspension, and steering system, and both are required to service and adjust steering systems and to remove and replace clutches. Information concerning these requirements is discussed in this chapter. The ASM service rating is assigned several additional requirements concerning the maintenance of these systems and components. Information concerning these requirements is contained in the Rate Training Manual, Aviation Support Equipment Technician M 3 & 2, NavPers 10315 (Series).

POWER TRAIN

In addition to the components required to transmit the power developed by the engine to the drive wheels, the power train of some self-propelled vehicles includes the components necessary to transmit the engine power to auxiliary or servicing equipment. For example, the foam pump and handline pump of the MB-5 Crash, Fire, and Rescue Truck (described in chapter 4) are powered by the main engine through components of the power train. Although they are not usually classified as power trains, similar components (clutches, gear systems, etc.) are used to transmit engine (or electric motor) power to the servicing components of some nonself-propelled equipment. For example, the air compressor described in chapter 13 is equipped with a clutch to disengage the engine from the compressor. This relieves the strain that would be put on the engine and starter if the compressor were operating during engine starting and warmup periods.

Consider the power train required in a two-wheel (rear) drive vehicle. In the process of transmitting power from the engine to the driving wheels, the power train provides the following:

1 A means of engaging the engine to, and disengaging it from, the drive wheels.

2. Several different gear ratios between the engine and the drive wheels.

3. A means of changing the direction of rotation (forward and reverse gears) of the drive wheels.

4. A means that permits one drive wheel to turn at a different speed than the other.

The basic components of a power train include a clutch, transmission, propeller shaft and universal joints, differential, and axles. Additional components, one or more of which may be found in different power trains, are fluid couplings, torque converters, transfer cases, and auxiliary transmissions.

The functions of these components are explained in the following paragraphs. (The different types of axles used in support equipment are described in chapter 11 of this training manual.)

NOTE: Basic Machines, NavPers 10624 (Series), contains an entire chapter devoted to the power train in which most of the above listed components are described and illustrated. As a result, these components are described only briefly in the following discussion. Emphasis is on those components which are not adequately covered in Basic Machines and some of the applications and different arrangements of power trains in ground support equipment. Therefore, for a better understanding of the functions and operations of the components of the power train, the appropriate chapter in Basic Machines should be studied in conjunction with the following information.

CLUTCH ASSEMBLIES

The clutch is the mechanism in the power train that engages the engine crankshaft to, or

disengages it from, the transmission and, thus, the remainder of the power train. The clutch is usually associated with the clutch pedal and the manually operated gearshift transmission. This type of clutch is discussed in this section. However, it should be mentioned at this time that the automatic transmission also requires some type of clutch which is usually controlled automatically. This clutch is usually considered part of the transmission and, therefore, is discussed with transmissions later in this chapter.

One purpose of the clutch is to allow the operator to uncouple, temporarily, the engine from the transmission. This permits the transmission gears to be shifted from one forward gear to another, to and from reverse, and to and from neutral without clashing of gears. In neutral, engine power cannot be transmitted through the transmission, even when the clutch is engaged. Thus, the engine can be started and brought to speed without delivering power through the transmission.

The other purpose of the clutch is to allow the operator to couple the engine to the transmission and driving wheels after the engine has been started and after shifting from one gear to another. The engaged clutch allows the engine to take up the load of driving the vehicle gradually and without shock.

To provide these functions, the clutch is located in the power train between the engine and the transmission. In most power trains, the driving member of the clutch is secured directly to the engine flywheel. However, in some vehicles, a gearbox is incorporated between the engine and the clutch. An example of a power train of this type is presented later in this chapter.

Types and Operation

The type of clutch used on self-propelled ground support equipment depends upon several factors, including the maximum engine torque developed, the type of transmission, and the nature of the service in which the clutch will operate. Although there are several different types of clutches, for example, the wet disc, electric, etc., the type most widely used in support equipment is some form of the dry disc, or plate clutch. The dry disc clutch may contain one, two, or more discs. A single disc clutch is used in most light vehicles, while double disc or multiple disc clutches are used in the heavier and more powerful vehicles. They are substantially the same with the exception of the number of driven discs and intermediate driving or pressure plates. A double disc clutch similar to the type used in the MRS-190 tractor (described in chapter 4) is illustrated in figure 16-1. View (A) shows a cutaway view of the clutch assembly and view (B) shows an exploded view of the major components.

Like most types of clutches, the double disc clutch transmits power from the clutch driving members to the driven members by friction. Referring to figure 16-1, each component of the assembly, with the exception of the discs (1 and 3), the clutch shaft (19), the yoke (9), and the housing of the release bearing assembly (10), is secured in some manner to the engine flywheel and, therefore, rotates with the flywheel. This includes the release bearing since the inner race of the bearing turns with the release sleeve (12) and the flywheel. The components that rotate with the flywheel are free to rotate about the clutch shaft (19). The two pressure plates (2 and 4) are considered the driving members of the clutch. Each disc has four lugs which fit into slots in the flywheel ring (5). The flywheel ring is secured to the engine flywheel with capscrews and washers. The two discs (1 and 3), which are considered the driven members of the clutch, are connected to the splines of the clutch shaft (19). The clutch shaft, in turn, is connected to the main drive gear of the transmission. When the driving members (2 and 4) make contact with the driven members (1 and 3), friction between the adjoining surfaces causes the driven members to turn with the driving members, thus, engaging the transmission with the engine.

The clutch is controlled by the operator with a clutch pedal which is connected by mechanical linkage to the clutch release yoke (9). The clutch is released (disengaged) by depressing the foot pedal. This moves the yoke, which pulls the release bearing assembly (10) away from the flywheel. As viewed in figure 16-1, this movement is from left to right. This force is transmitted through the release sleeve (12) and the release sleeve retainer (18) and compresses the pressure springs (14 and 15). This relieves the spring load on the clutch lever (21) and the pressure plate (4). The pressure plate pull-back springs (17) retract the pressure plate, releasing the lockup between the driven discs (1 and 3) and the pressure plates (2 and 4).

The clutch is engaged by releasing the pressure on the clutch pedal. This moves the yoke (9), which allows the release bearing assembly (10) to move toward the flywheel. This, in turn, allows the pressure springs (14 and 15) to exert force on the multiple lever. As shown in view (B) of figure 16-1, this lever assembly consists of several metal levers attached to a hub. The pressure exerted by the pressure springs to the lever is increased by the lever ratio between the fulcrum points (X, Y, and Z). (See view (A), fig. 16-1.) The multiplied force is transmitted to the pressure plate (4). This forces the pressure plates and the driven discs to make contact and engage the clutch.

To provide smooth operation, the clutch should be engaged gradually. This is controlled by releasing the clutch pedal gradually. When the driven discs and the pressure plates first make contact, there is little friction between the members, and the clutch is permitted to slip. As the clutch pedal is released, the members move closer together, friction increases, and slippage decreases. When the clutch pedal is fully released, all slippage stops and the clutch is engaged.

Clutch Facings

Linings are attached to both sides of the driven discs. These linings, commonly referred to as clutch facings, are usually made of asbestos fiber interwoven with brass wire. They may be bonded to the metal disc; however, in most cases, they are riveted, as shown in view (A) of figure 16-2. Another type of facing, illustrated in view (B), is in the form of a button, several of which are riveted to each side of the metal disc. These buttons are made as a mixture of metal and ceramic material. Either type of these facings can be used in the double disc clutch illustrated in figure 16-1. The asbestos/wire facings are shown in the illustration; however, when used in the MRS-190 low tractor, this clutch is equipped with the ceramic button type facings.

Clutch facings will wear when the clutch slips. Of course, some slippage is required to engage the clutch smoothly. However, if the driver "rides" the clutch to rest his foot, he causes the clutch facing to slip slightly. This results in unnecessary wear of the facings. To compensate for this wear, the clutch must be adjusted from time to time. On some clutches, this adjustment can only be made on the linkage between the clutch pedal and release bearing. In addition to this adjustment, some clutches, such as the double disc clutch illustrated in figure 16-1, are equipped with an adjusting ring for internal adjustments. These adjustments are explained later.

When worn excessively, the clutch facings must be replaced. In some cases, each driven member (the steel disc and facings) is replaced as a unit. For example, it is recommended that discs with ceramic button type facings be replaced as a unit. In some cases, the asbestos/wire type facings may be removed from the disc and replaced with new ones. The facings are removed from the disc by pin punching the rivets on the riveted side. It is usually easier to spot drill the rivets and then punch them out.

The new linings are fastened to the disc at the same time; that is, the front and rear linings are placed on the respective sides of the steel clutch disc and then the rivets are placed through both linings and the disc simultaneously. Half of the rivets should be installed through the front lining and the other half through the rear linings. While replacing these linings, the unit must be handled carefully to prevent distortion and to keep it clean. A distorted driven member will prevent proper clutch adjustment, and oil or grease on the facing will cause the clutch to slip.

Clutch Adjustments

As stated previously, clutches must be adjusted from time to time to compensate for facing wear. The procedures for clutch pedal adjustment and internal clutch adjustments are described in the following paragraphs.

NOTE: Personnel of the ASM service rating are responsible for the adjustments of clutches. However, since the ASH must be able to remove and replace clutches, he should be familiar with adjustment procedures.

PEDAL ADJUSTMENTS.—The clutches on some large vehicles require a great amount of pressure to compress the release springs and, therefore, are equipped with hydraulic clutch release systems. However, the clutches most commonly used on support equipment are operated with a direct mechanical linkage between the clutch pedal and the clutch release yoke. A linkage of this type, featuring the adjustment points, is illustrated in figure 16-3.

The toeboard clearance screw (eliminated on some newer vehicles), shown in figure 16-3,

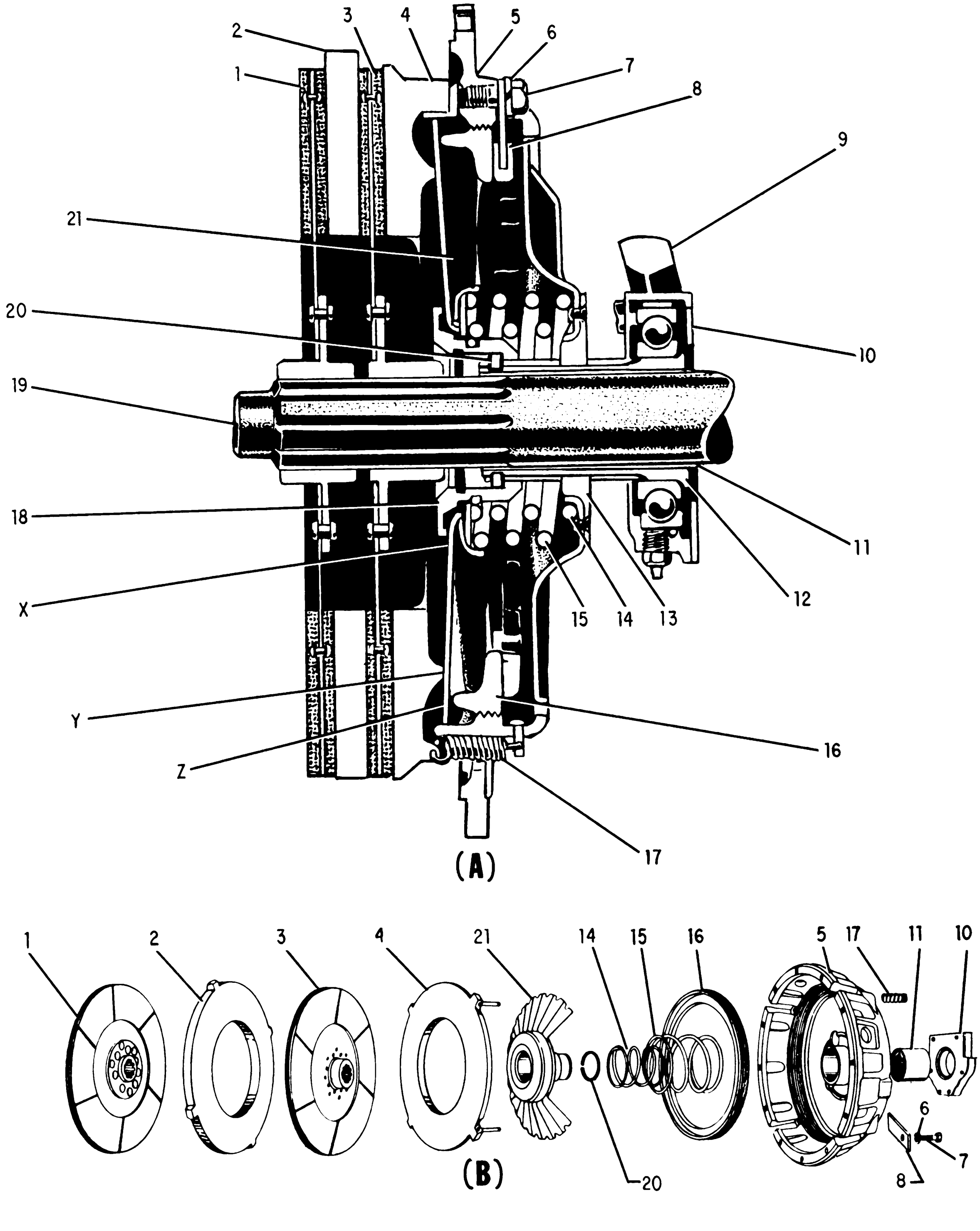

Figure 16-1.—Double disc clutch assembly. (A) Cutaway view; (B) exploded view of major components.

Nomenclature for figure 16-1.

1. Driven disc, front.	9. Clutch release yoke.	17. Pull-back spring.
2. Intermediate pressure plate.	10. Release bearing assembly.	18. Release sleeve retainer.
3. Driven disc, rear.	11. Flywheel ring bushing.	19. Clutch shaft.
4. Pressure plate.	12. Release sleeve.	20. Release sleeve snap ring.
5. Flywheel ring.	13. Spring plate hub.	21. Clutch lever.
6. Lock washer.	14. Pressure spring, inner.	X. Fulcrum point.
7. Adjusting ring lock screw.	15. Pressure spring, outer.	Y. Fulcrum point.
8. Adjusting ring lock.	16. Adjusting ring.	Z. Fulcrum point.

should be adjusted so that the clearance between the clutch pedal arm and the toeboard is 1/2 to 3/4 inch. A clutch pedal return spring returns the pedal to the normal position.

The screw adjustment in the tie rod between the pedal and the release yoke must be adjusted periodically to compensate for normal wear of the clutch facings. After loosening the locking nut and unfastening one end of the tie rod, the length of the rod can be increased or decreased by turning the loose end. The length of the rod must be adjusted to allow 3/4-inch to 1-inch free movement of the clutch pedal. (See figure 16-3.)

The point where the free movement ends and the clutch begins to release can be felt by the increased pressure required to depress the pedal. If there is not sufficient free movement, the clutch release bearing, commonly referred to as the throwout bearing, will partially compress the clutch springs. This will result in clutch slippage and damage to the pressure plates, the facings, and the throwout bearing. Too much free movement may keep the clutch from completely disengaging, thereby making it impossible to shift the transmission with the engine running. After making this adjustment, be sure to tighten the locknut, and lock the clevis pin position with a new cotter pin.

INTERNAL ADJUSTMENT.—As mentioned previously, some clutches are equipped with mechanisms for internal adjustment. The double disc clutch illustrated in figure 16-1 is equipped with one type of internal adjustment. To make the internal adjustment on this type clutch, proceed as follows:

1. Remove the inspection cover at the bottom of the clutch housing.
2. Measure the clearance between the release bearing assembly (item (10), fig. 16-1), and the spring plate hub (13). The clearance differs with the size and installation of the clutch. This clearance on the 15 1/2-inch, double disc clutch used on the MRS-190 should be approximately 17/32 inch. If the clearance is not correct, readjust the clutch as follows:
3. Rotate the engine flywheel until the adjusting ring lock (8) is exposed. Remove the lock screw (7) and the lock (8).
4. Release the clutch by locking the clutch pedal down in the depressed position.
5. Use a pry bar to turn the adjusting ring (16). Turn the adjusting ring counterclockwise to move the release bearing assembly toward the flywheel; clockwise to move the bearing away from the flywheel. Rotation or movement of one lug position will move the release bearing housing approximately 1/32 inch.
6. Remove the clutch pedal block to engage the clutch.
7. Recheck the clearance as outlined in step 2.
8. After the clutch has been properly adjusted, install the lock (8) with the lock screw (7) and the lock washer (6) in the notch provided in the adjusting ring.

Clutch Removal and Replacement

As mentioned previously, most of the maintenance required on clutches is the responsibility of the ASM service rating. This includes such maintenance as troubleshooting malfunctions, servicing, adjusting, and inspecting the clutch assembly and the connecting linkages. However, the removal and replacement of clutches are requirements for both the ASM and ASH service ratings.

Clutches must be removed from time to time to correct malfunctions. For example, driven discs must be replaced or refaced when the facings are worn excessively. In addition, weak

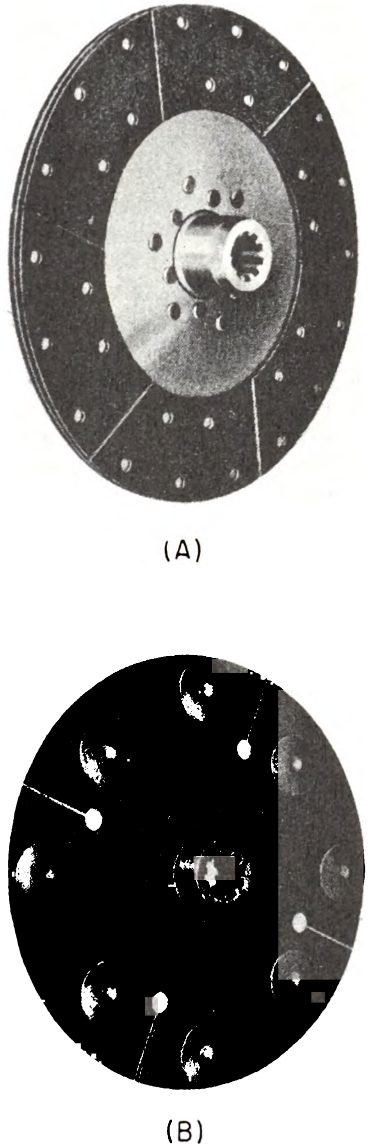

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Figure 16-2.—Clutch facings.
(A) Asbestos wire type;
(B) ceramic button type.

or broken springs must be replaced. These and other repairs require the removal of the clutch assembly.

The procedures for removing and replacing the double disc clutch illustrated in figure 16-1 are presented as follows:

NOTE: Variations in design and construction make it necessary to use somewhat different

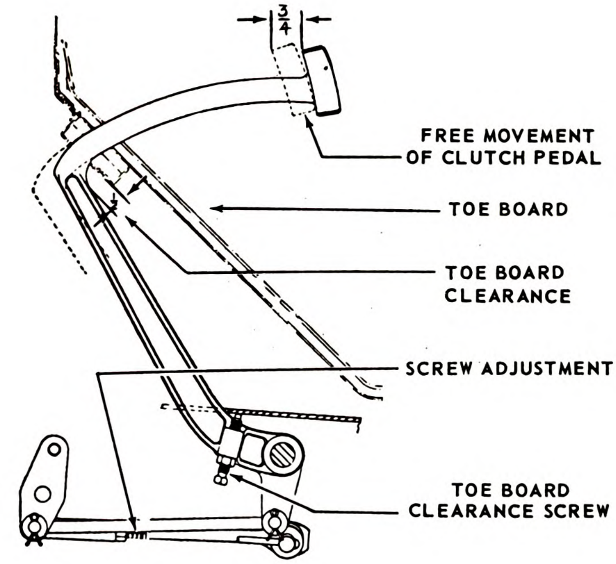

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Figure 16-3.—Clutch pedal adjustments.

procedures and tools when removing and replacing clutches on different types and models of support equipment. Therefore, the applicable technical publications must be consulted when performing this type maintenance on specific items of equipment.

1. Remove the transmission. The applicable technical manual must be consulted for this step.

CAUTION: A suitable jack should be used to properly support and maintain engine/transmission alignment when removing the transmission from the engine. Do not allow the transmission to drop and hang unsupported in the splined hub of the clutch disc or "sprung" clutch discs will result.

2. After the transmission has been removed, insert two 3/4-inch blocks of wood between the release bearing assembly (10) and the spring plate hub (13). This facilitates the removal of the clutch-to-flywheel capscrews and protects the pull-back springs (17) from excessive tension.

3. Remove the clutch retaining capscrews and remove the pressure plate and flywheel ring assembly.

4. Remove the rear driven disc (3), the intermediate pressure plate (2), and the front driven disc (1).

The applicable technical manual should be consulted for further disassembly procedures. All components should be inspected and repaired or replaced if necessary.

Before installing any clutch, it is advisable to check the following items:

1. Remove the flywheel pilot bearing and inspect for excessive looseness and end play. Examine the balls and races for flaking, pitting, or scoring. Check the ball retainers or cage for loose or broken rivets and cracks in the cage itself. If defective, or questionable, always install a new pilot bearing.
2. Prior to the installation of pilot bearings, check for proper fit of the inner and outer races. This should be a light finger press fit on both the transmission main drive gear stem and the flywheel bore. Prepack the pilot bearing with high temperature grease at the time of installation.

With the two 3/4-inch blocks of wood in place (see step 2 of the removal procedures), the clutch is installed as follows:

1. Insert a spline aligning tool (or the main drive gear from the transmission) through the clutch assembly to align the two clutch discs and to keep the clutch parts in place during assembly to the flywheel.
2. Position the assembly on the flywheel, making certain that the pilot end of the aligning tool has entered the pilot bearing.
3. Start all twelve retaining capscrews with lock washers to locate and retain the clutch assembly in place.
4. Tighten the capscrews, progressing evenly around the flywheel to avoid cocking and binding the flywheel ring pilot. Tighten screw to 35-40 foot pounds torque.
5. Remove the two 3/4-inch wooden blocks from between the clutch release bearing (10) and the spring plate hub (13).
6. Remove the spline aligning tool.
7. Rotate the clutch release yoke (9) so that the top is positioned toward the transmission.
8. Shift the transmission into gear.
9. Position the release bearing assembly (10) so that the flat section of the housing is on top.
10. Use a suitable jack to properly support and maintain the engine/transmission alignment when installing the transmission. Raise the transmission and align it with the engine. Enter the drive gear of the transmission through the clutch release bearing sleeve and move it ahead to pick up the driven disc splines. Turn the companion flange of the transmission to align the splines of the drive gear with the clutch driven discs.

CAUTION: Use care to avoid springing the clutch or driven discs when the transmission is being installed. Do not force the transmission into the clutch or engine bell if it does not enter freely. Do not let the transmission drop or hang unsupported in the splined hub of the clutch discs or "sprung" clutch discs will result.

11. As the transmission is entering the clutch and flywheel, turn the fingers of the clutch release yoke (9) down over the clutch release bearing housing into their proper position.
12. After the transmission is secured to the engine, check the internal adjustment as outlined previously. Reset this adjustment at this time, if required.
13. After setting the internal clutch adjustment, set the external clutch linkage and pedal travel.
14. If new clutch disc facings were installed, repeat steps 12 and 13 above, after one or two days of operation.

TRANSMISSIONS

If the power requirements between the engine and the drive wheels were relatively constant, a power train consisting of a drive shaft and some type of clutch to obtain gradual application of the load on the engine would be sufficient. Speed could be regulated by the engine throttle. However, this is not the case with self-propelled automotive vehicles. Whether the vehicle is the family automobile, an aircraft tow tractor, a crash, fire, and rescue truck, or a weapons loader, a great deal more power is required to start the vehicle in motion than to keep it in motion. Also, power requirements will vary with the load on the vehicle. In addition, both forward and reverse movements are required. Therefore, some type of speed and power changing device is required in the power train. This device is the transmission.

When discussing the transfer of power from the engine to the drive wheels, the terms torque and speed must be considered. Torque is a twisting force which produces or tends to produce rotation or torsion. The engine power applies this twisting force to the shafts and other rotating members of the power train.

With this in mind, consider a small gear (10 teeth) keyed to a shaft (driving), extending from

the crankshaft, and meshed with a larger gear (20 teeth), which is keyed to a second shaft (driven). The driving shaft is parallel to the driven shaft. The power from the engine applies torque to the driving shaft. As the driving shaft turns, the teeth of the smaller gear apply torque force to the teeth of the larger gear which, in turn, apply torque to the driven shaft. Since the distance from the center to the rim of the larger gear is greater than that of the smaller gear, the twisting force or torque applied on the driven shaft is greater than the torque of the driving shaft. Therefore, the torque applied by the engine has been increased.

In this process of increasing the torque something must be lost or decreased. It requires two revolutions of the small gear (10 teeth) for one revolution of the large gear (20 teeth), which is a gear ratio of 2 to 1. Therefore, as the torque increases, speed decreases and vice versa.

By altering the sizes of the gears on either or both shafts, almost any combination of speed and torque can be obtained. Of course, this range of speed and torque must be within the capabilities of the engine. Basically, this is what a transmission accomplishes by means of gears or some other methods.

NOTE: Basic Machines, NavPers 10624 (Series), should be consulted for detailed information concerning the types of gears and the manner in which gears must be arranged to change the speed, torque, or direction of rotation of a shaft.

There are many different types of transmissions; however, most can be classified into two classes—the standard and the automatic. In the standard transmission, the operator must manually shift the transmission from one speed/torque ratio to another. This, of course, necessitates the use of the manually operated clutch, described previously. With the automatic transmission, the operator selects neutral, reverse, or several different ranges of forward speed. The transmission automatically shifts from one forward speed/torque ratio to another. This transmission does not require a manually operated clutch.

Standard Transmissions

Some types of ground support equipment are equipped with standard transmissions. The conventional three-speed transmission is used on some types. This transmission provides reverse, neutral, and three forward speeds, similar to the standard transmission used on automobiles. However, since support equipment is usually operated at much lower speeds and requires a great amount of power at these low speeds, the speed and torque ratio is different than that of automobile transmissions.

Four-speed (forward) transmissions are used on some types of equipment. Certain items of equipment require six or more forward speeds and two reverse speeds. This is usually accomplished with a combination of a standard transmission and an auxiliary transmission. For example, a combined three-speed transmission and two-speed auxiliary provides six speeds forward and two reverse speeds.

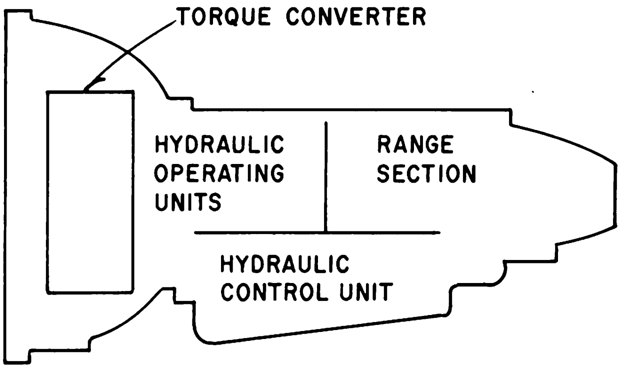
The older types of standard transmissions were equipped with spur gears. Later models employ helical gears and, in addition, certain gears are constantly in mesh with other gears. This type is known as the constant mesh transmission. The synchromesh transmission is a later model of the constant mesh transmission that permits gears to be selected without clashing, by synchronizing the speeds of mating parts before they engage.

These three types of standard transmissions are adequately described and illustrated in Basic Machines, NavPers 10624 (Series) and, therefore, are not discussed in this manual.

Automatic Transmissions

For many years automotive engineers and inventors searched for ways of making gear shifting easier in power-driven automotive equipment. The search for improved gear shifting was not only for personal convenience, but also for reduced maintenance (such as burned out clutches and stripped gears) and increased safety.

In recent years, automatic devices have been developed which can give semiautomatic or automatic operation to the vehicle's power train. The latest models of most types of self-propelled support equipment are equipped with automatic transmissions. For example, modern tow tractors usually employ automatic transmissions to provide a smoother coupling of the engine to the drive wheels. Automatic transmissions also free the operator from operating the clutch and allow him to concentrate more on towing the aircraft or equipment; therefore, a smoother, safer move is made.



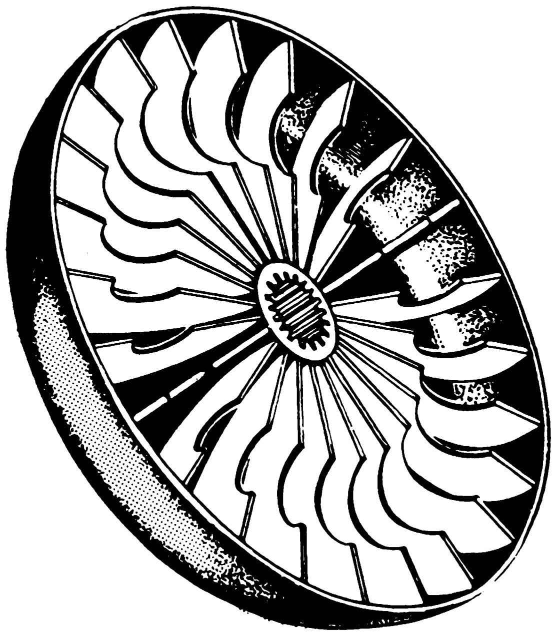
AS.79
Figure 16-4.—Automatic transmission—major components.

The components of an automatic transmission can be divided into four groups—the torque converter, the range or gearing section, the operating units, and hydraulic control units. These four groups are illustrated in figure 16-4. The functions of these components are briefly described in the following paragraphs.

NOTE: The ASM service rating has additional requirements concerning the principles of power transmission components and systems and the servicing, adjustments, and repair of transmissions. Therefore, the automatic transmission is covered in greater detail in the rate training manual, Aviation Support Equipment Technician M, 3 & 2, NavPers 10315 (Series).

Before discussing the torque converter, a brief description of the fluid coupling is in order. This is the simplest means of transmitting torque hydraulically. Fluid couplings can be used with automatic transmissions or with a clutch and a standard transmission. In modern vehicles, however, the fluid coupling is generally used with automatic transmissions.

The fluid coupling consists of two main parts, the driving member of the unit and the driven member. The driving member is called the PUMP and the driven member the TURBINE. Not all manufacturers choose to use these names when writing about the fluid coupling. Sometimes the pump is called the impeller, or driver; the turbine may be called the runner. Often the two members are called FRONT TORUS and REAR TORUS. (A torus is any doughnut shaped object.)



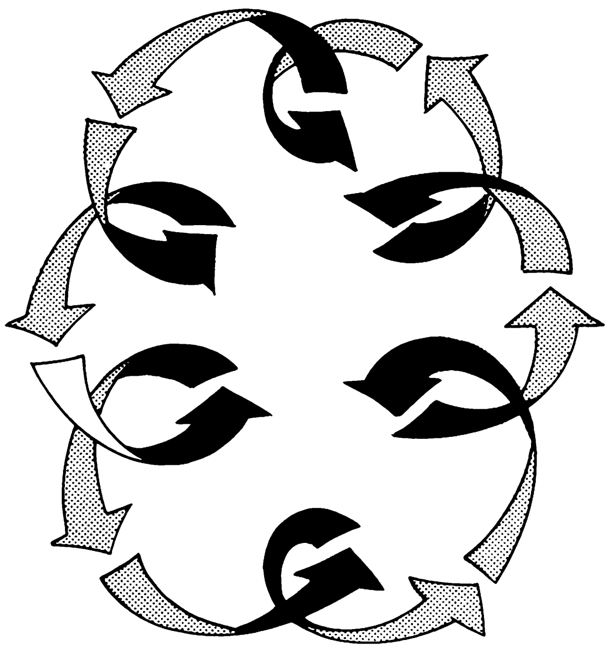
AS.613
Figure 16-5.—Fluid drive pump.

The pump of the fluid coupling is connected to the engine and is rotated in the same manner that a crankshaft rotates a flywheel. Usually, the pump is bolted directly to the flywheel. The pump is a torus-shaped object that has fins extending radially from its center. (See fig. 16-5.)

The turbine is made exactly like the pump but is connected to the transmission input shaft. The two members of the coupling face each other within a housing that is filled with the driving fluid (generally oil).

When the pump goes into motion, oil is forced outward by centrifugal force around the entire circumference of the pump and hurled against the blades of the turbine. A continuous flow of oil against the turbine blades is necessary to transfer sufficient kinetic energy to keep a vehicle in motion.

The centrifugal force of the oil as it leaves the pump gives the oil the velocity it needs. The faster the pump operates, the more velocity the oil leaving the pump will have. The design of the coupling permits the oil to return to the pump as soon as it has delivered its energy to the turbine.



AS.614
Figure 16-6.—Schematic of vortex flow in a liquid.

Where the vehicle has not started to move, the turbine is stationary. For instance, the engine may be rotating the pump at 900 rpm. The pump is consequently imparting energy to the fluid which in turn imparts energy to the turbine. By the time the oil returns to the pump, the pump has moved some distance, making it impossible for the oil to reenter the pump through the same set of vanes it left. Consider one drop of oil; the drop would follow a path that looks something like a string wound around a doughnut through the hole. (See fig. 16-6.) This path of oil is called a vortex, and is the path of the stream of oil which drives the turbine. There are as many vortex streams in a fluid coupling as there are fins.

As the turbine begins to turn, the difference in speed between the pump and the turbine decreases. As the speed difference decreases, the coils of the vortex become closer together. A LOW VORTEX exists when the pump and turbine are traveling at nearly the same speed. A HIGH VORTEX exists when the pump and turbine speeds differ greatly.

The higher the vortex, the greater is the driving power of the oil. When the vortex is high, the oil tends to strike the fins on the turbine at nearly a right angle.

The degree of vortex is continually changing and is determined by the difference in speed between the members of the coupling.

A condition known as "Zero Vortex" or "Fluid Coupling Stage" would exist only when the two members of the fluid coupling were turning at exactly the same speed. When this happens the fluid coupling actually has no driving power. The pump, turbine, and the fluid within the coupling are all turning as one unit in a rotary motion.

The fluid coupling stage seldom exists, however, since the turbine will always lag a little behind the pump when there is a load on the vehicle. The fluid coupling stage will exist momentarily when the vehicle begins to coast or reduce speed. As soon as the engine slows down, the momentum of the vehicle will cause the turbine to throw a vortex of oil at the pump, thus permitting the engine to help reduce the speed of the vehicle by creating a drag.

Within fluid couplings, shock loads can never be transmitted into the engine. Sudden gear-breaking jerks are impossible. If a vehicle is overloaded, the fluid coupling will slip and will never allow the engine to become overloaded. Thus, harmful low-speed lugging of the engine is impossible. Vibrations and irregularities of the engine can be harmful to the rest of the vehicle's power train. With fluid couplings, it is impossible for these engine irregularities to be transmitted to the power train.

The torque converter may be thought of as a special form of the fluid coupling. The torque converter has driving and driven members with vanes. Oil is passed from the driving to the driven member when the coupling is in operation, thereby transmitting driving force to the driven member.

One of the principle differences between the torque converter and the fluid coupling is that the vanes of the members of the torque converter are curved. Another difference in construction is the addition of other members between the driving and driven members. These additional members are called STATORS. The function of the stators is to redirect the vortex of oil as it returns to the driving member. The returning oil from the driven member would act as a brake on the driving member if the oil and the driving member did not have the same

direction. The vortex helps to drive the pump rather than opposing the pump.

The torque converter not only acts as a fluid coupling but also provides a speed-producing, torque-multiplying connection between the driving and the driven shafts. It can actually take the place of the conventional transmission since, with a torque converter, there is no need for manual gear shifting. The vehicle can be accelerated from a standing stop to high speed with the torque converter providing, in effect, the varying gear ratios. In actual practice however, the torque converter is used with a gear system to provide an optimum speed/torque combination. This is the first component shown in figure 16-4.

The range, or gear, section, shown in figure 16-4, contains a planetary gear train, which consists of two or more planetary gear units. A planetary gear system consists of a central sun gear surrounded by two or more planet pinion gears which are, in turn, meshed with a ring (internal) gear. There are several different combinations of speed/torque ratios available through a planetary gear system. This depends on the number of planetary units used in a system and on which gears are driving gears, stationary gears, or driven gears.

The operating units of the transmission are servos and clutches. These components are usually hydraulically operated and control the movement of different members of the planetary gear system. The servo unit is used for holding one member of the planetary unit, while the clutch is used for holding two members. Different combinations of speed/torque ratios are thus provided.

In the manual selective type transmission, the operator must select the gear ratios he thinks are best for engine loads and vehicle speeds. However, in the automatic transmission, it is the job of the hydraulic control units to make the proper selection (gear ratio) for the engine load and vehicle speed and to make the selection at the proper time.

A typical system of hydraulic control units consists of many components. Some of these components sense vehicle speed, others sense engine power, some supply hydraulic pressure, and still others regulate and control the hydraulic fluid and pressure.

As can be seen the automatic transmission is a complex mechanism. It is shifted through a system of hydraulically operated clutches, bands, servos, governors, and valves. The pump provides a means of developing hydraulic pressure. This hydraulic pressure is directed by various valves to the hydraulic clutches and servos that control the planetary gears. The operation of the various valves in the automatic transmission is a mechanical and hydraulic balance, controlled by the governor pressure, throttle valve pressure, or spring pressure. The manual control lever selects the range of transmission operation.

Auxiliary Transmission

As mentioned previously, auxiliary transmissions are used with other transmissions to obtain a greater number of speed/torque ratios for heavy equipment. In appearance and operation, auxiliary transmissions are similar to main transmissions. They usually provide two ranges for the main transmission. One is the direct range and the other is a lower range. Some have a third range, referred to as the overdrive.

Transfer Cases

Transfer cases are placed in the power trains of vehicles driven by all wheels. Their purpose is to provide the necessary offsets for additional propeller shaft connections to the drive wheels.

Transfer cases are usually equipped with some type of clutch for connecting and disconnecting the transmission from the drive wheels. On some vehicles, the transfer case is equipped with two speed positions and, therefore, also serves as an auxiliary transmission.

PROPELLER SHAFT ASSEMBLIES

The propeller shaft assembly consists of a propeller shaft, a slip joint, and one or more universal joints. The propeller is the drive shaft that transmits the power from the transmission to the differential. The slip joint is necessary because the movement between the transmission and differential requires that the propeller shaft be able to shorten or lengthen itself. On vehicles having rear springs the differential moves up and down as the rear wheels move over uneven surfaces. This up and down movement lengthens and shortens the distance between the transmission and the differential. On vehicles such as tow tractors that have no rear springs, the slip joint is necessary

because the distance between the transmission and the differential still increases and decreases when the vehicle moves over uneven surfaces. Vibration of the engine on its shock mounts and expansion and contraction also necessitate a slip joint.

The usual type of slip joint consists of a splined shaft that fits into a splined sleeve. The splines permit the continuing transmission of power as the sleeve moves back and forth on the shaft.

The propeller shaft is usually equipped with one or more universal joints to take care of the changes in the angle of the drive. A univeraal joint is essentially a double-hinged joint through which the drive shaft can transmit power to the driven shaft even though the two shafts are some degrees out of line with each other.

Each of the two shafts has a Y-shaped yoke on the end, and between these yokes there is a center member that is shaped like a cross. The four arms of the center member are assembled in bearings at the end of the shaft yokes. The bearings can turn on the crossarms to take care of any angularity between the shafts as the shafts rotate. The driving shaft causes the center member to rotate by its pressure on two of the crossarms. The other two crossarms cause the driven shaft to rotate.

DIFFERENTIALS

The differential is connected to the propeller shaft by the final drive. The final drive consists of a pinion gear driven by the propeller shaft. The pinion turns a ring gear that is part of the differential. The function of the ring gear and pinion is to change the direction of the power transmitted through the propeller shaft by 90 degrees in order to drive the axles. The ring gear and pinion also provide fixed reduction between the speed of the propeller shaft and the axles. The gear ratio is determined by dividing the number of teeth on the ring gear by the number of teeth on the pinion.

Most aviation support equipment have bevel gears in the final drive. Spur bevel gears are very noisy; therefore, spiral gears are used on most equipment. The ring gear and pinion are housed in the differential housing.

The purpose of the differential is to adjust for the difference in distance the drive wheels travel when the vehicle turns. For example, if a 90 degree turn is made on a 20-foot radius, the inner wheel would travel about 31 feet and the outer wheel would travel nearly 39 feet. The differential permits each axle to turn at a different rate and still be driven as a single unit.

The operation of different types of differentials is adequately covered in Basic Machines, NavPers 10624 (Series) and, therefore, is not repeated here.

COMPONENT ARRANGEMENT

In the conventional two-wheel (rear) drive vehicle, the power train is arranged in a line between the engine and the rear axles. The clutch and standard transmission, or the automatic transmission, connect directly to the rear of the engine. The propeller shaft connects the transmission to the differential. If an auxiliary transmission is required, it is usually connected to the rear of the main transmission by a short propeller shaft and universal joint. If a transfer case is used, it is usually connected to the transmission in the same manner as the auxiliary transmission. It is connected to the differential by additional propeller shafts.

Similar power train arrangements, with the necessary components, are used on most types of self-propelled support equipment. However, some types require different arrangements. For example, the engine on some types of equipment is located in the rear of the vehicle. This, of course, requires a different arrangement. One example of this type of arrangement is illustrated in figure 16-7. This is the power train of the AERO 47A weapons loader.

In this assembly, power is taken from the engine through the main gearbox to the transmission and clutch by four gears. The rpm is increased in the main gearbox and power is transferred to the clutch, through the transmission, and into a transfer case. The transfer case transfers the power to a limited slip differential. There it is divided and directed to the rear wheel universal joints.

The main gearbox is connected onto the forward end of the engine. It directs engine power to the transmission through a dry clutch. The main gearbox is a series of four gears that turn and provide power to the piston and gear type hydraulic pumps and the tachourmeter (a device that registers engine rpm and records the hours of engine operation).

The clutch is located to the left of the engine and to the right of the operator's foot area. It

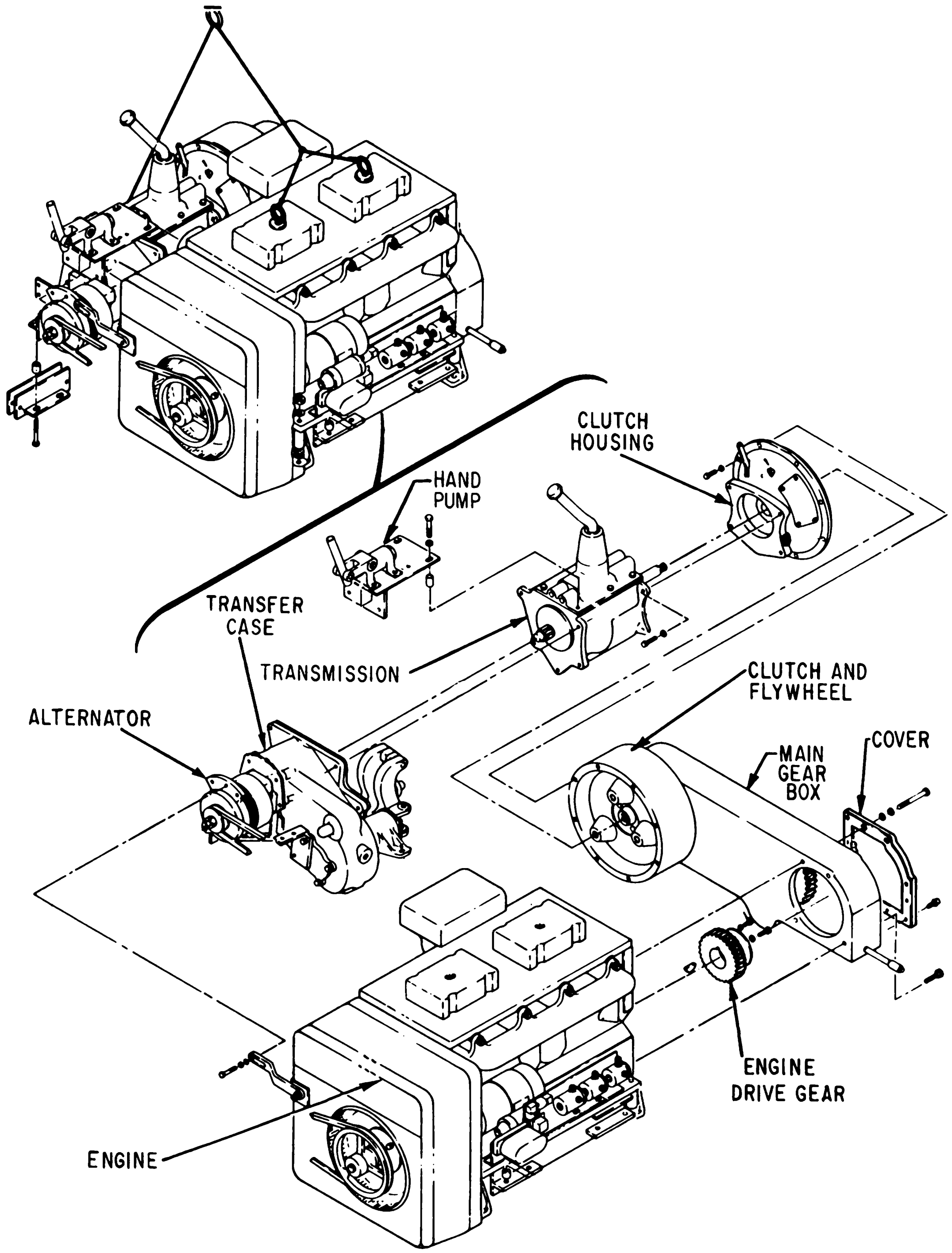


Figure 16-7.—Power train assembly—weapons loader.

is a conventional, automotive, single disc, dry clutch, linked to a foot control.

The transmission is of the conventional three-speed type, located to the left of the engine beside the operator's seat. The proper shift positions are marked on the gear shift knob and are identical to those on the conventional automotive gear shift.

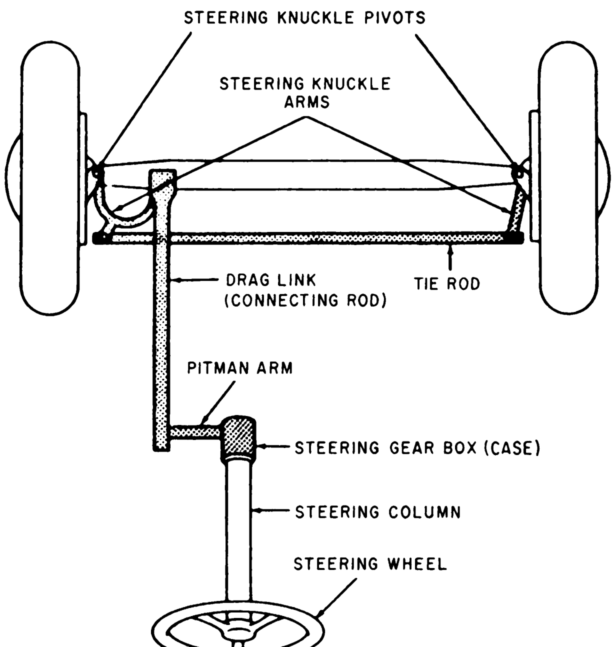


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Figure 16-8.—Diagram of steering mechanism.

A transfer case is mounted directly to the output end of the transmission. This arrangement permits the line of power to be directed downward and forward at this point in order to align with the differential.

Tractional power from the transfer case is transmitted through the drive shaft to a modified automotive limited slip differential and rear axle assembly.

STEERING SYSTEMS

Many of the vehicles maintained by the Aviation Support Equipment Technician rating are equipped with steering mechanisms. As stated in the introduction of this chapter, the ASM is primarily responsible for these systems; however, both the ASH and ASM must know the functions of steering system components and are required to service and adjust steering systems. The first part of this section pertains to the components and operation of mechanical steering systems. This is followed with information concerning power steering systems.

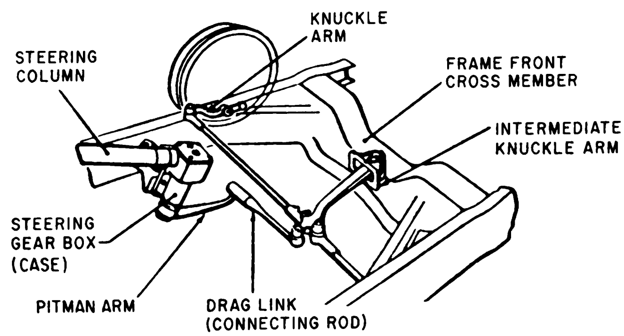

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Figure 16-9.—Steering assembly

Wheel alignment and steering adjustments and maintenance are described in the last part of the chapter.

MECHANICAL STEERING

Although steering a vehicle may be a simple operation, the steering mechanism is rather complex. A diagram of a steering mechanism is illustrated in figure 16-8, and an example of a steering assembly is illustrated in figure 16-9. The components peculiar to steering mechanisms are identified in these two figures.

All steering mechanisms have the same basic parts. The steering linkage ties the front or, in some cases, the rear wheels together and connects them to the steering gear case at the lower end of the steering column. In turn, this linkage connects the gear case to the steering wheel.

The arms and rods of the steering linkage have ball or ball and socket ends to provide a swivel connection between them. These jointed ends are provided with grease fittings, dust seals or boots, and many of them have end-play adjustment devices. These joints and devices must be adjusted and lubricated regularly.

The arms, rods, and joints of steering linkages on some types of support equipment may be arranged differently from those shown in figure 16-8. However, they are usually located in the same general area in the front (or rear) and underneath the vehicle.

The tie rod, for example, is usually located behind the axle on front-wheel drive vehicles and keeps the vehicle in proper alignment. To provide for easier steering and maximum

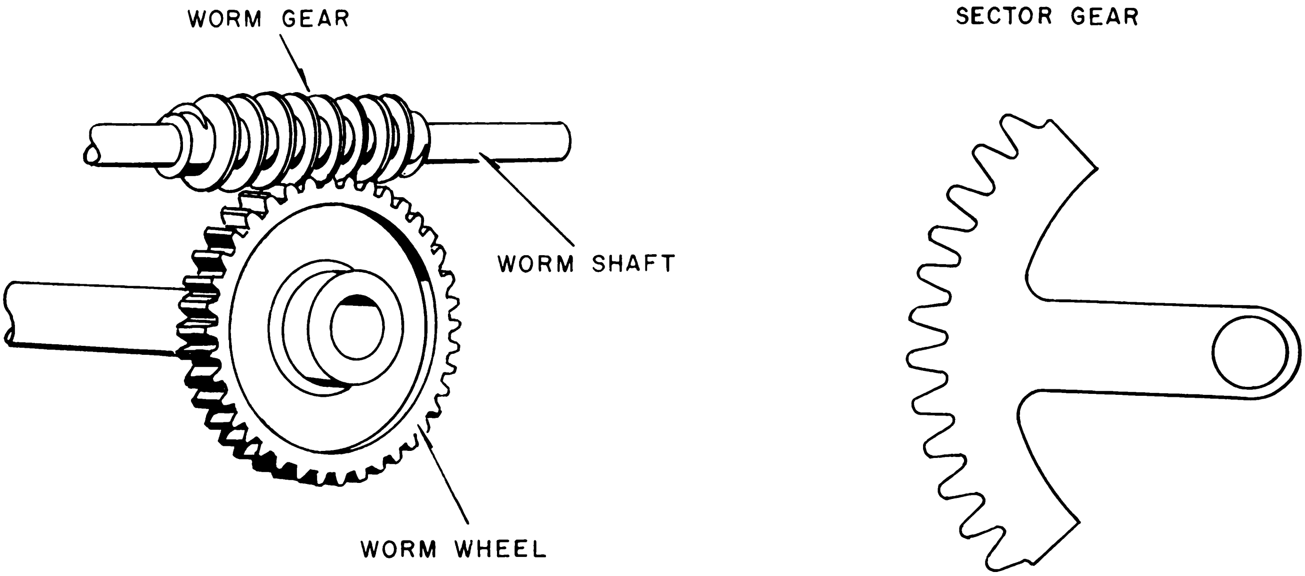


Figure 16-10.—Worm gear assembly.

leverage, the tie rod may be separated into two lengths and connected to the steering gear near the center of the vehicle. (See fig. 16-9.)

The rod (drag link) connecting the steering arm and the pitman arm may be long or short, depending on the installation.

The pitman arm, which is splined to the shaft extending from the steering case, moves in an arc. Its position depends upon the direction the wheels are turned. It is approximately vertical when the wheels are positioned straight ahead. Therefore, the length of the connecting rod (drag link) is determined by the distance between the steering arm and the vertical position of the pitman arm. Unlike the tie rods, the length of the drag link is not adjustable.

The steering case contains the mechanism which controls the movement of the pitman arm. This complete assembly converts the rotary motion of the steering wheel and shaft into straight-line motion of the drag link and tie rod. Most steering gear mechanisms operate on the same principle as the worm gear assembly illustrated in figure 16-10. Rotation of the worm gear turns the worm wheel; however, the worm gear must be rotated several revolutions in order for the worm wheel to turn one revolution. This ratio depends upon the number of teeth in the worm wheel and the number of threads in the worm gear. This mechanical advantage is required in the operation of the steering system.

Assume that the worm shaft (fig. 16-10) is the steering wheel shaft and that the worm wheel shaft is connected to the pitman arm. When the steering wheel is turned a complete revolution the pitman arm would turn only a few degrees. This gear ratio varies from 4:1 to 18:1 in automotive equipment. The high steering ratios are used in vehicles that are difficult to steer or slow moving. The low steering gear ratios are used in vehicles that are easy to turn.

To provide complete steering, the pitman arm only turns a fraction of a revolution. Therefore, only a small section of the worm wheel is used. For this reason, this type steering gear system is usually equipped with a sector gear, an example of which is illustrated in figure 16-10. This steering gear mechanism is referred to as the worm gear and sector type.

To provide easier and more efficient steering, roller and ball bearings have been added to the steering gear units. The design of the worm gear and sector differ in some types of steering gear mechanisms. As a result, the names of these parts differ. For example, in the cam and lever type unit illustrated in figure 16-11, the worm gear is called a cam and the sectors are called studs. However, these parts

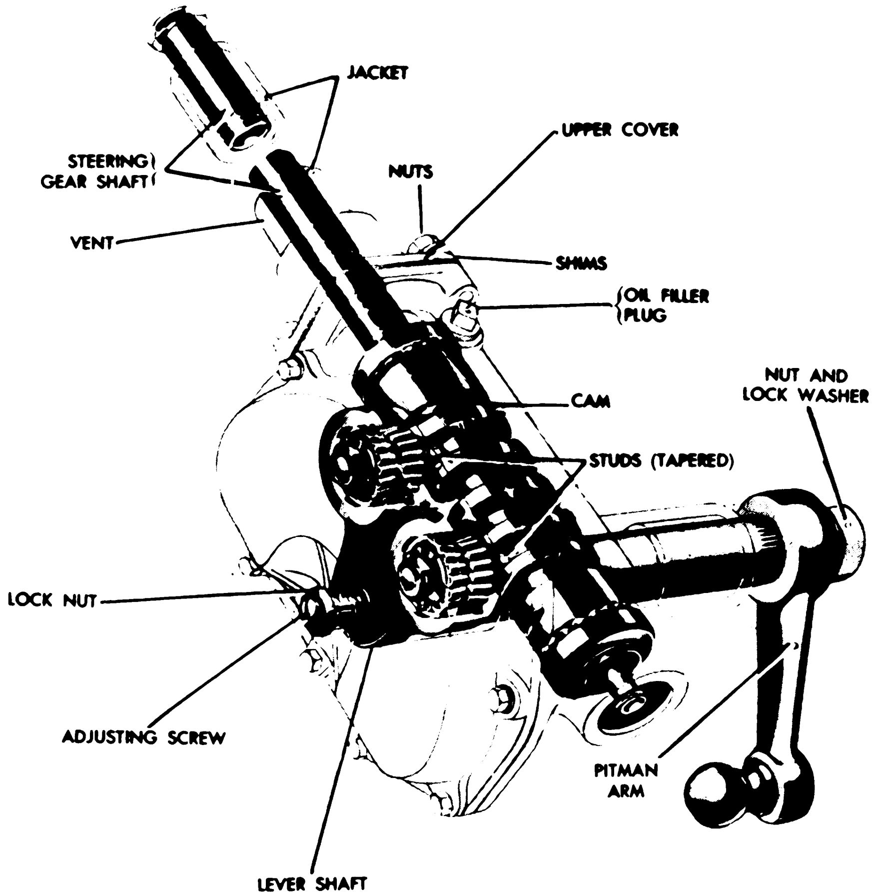


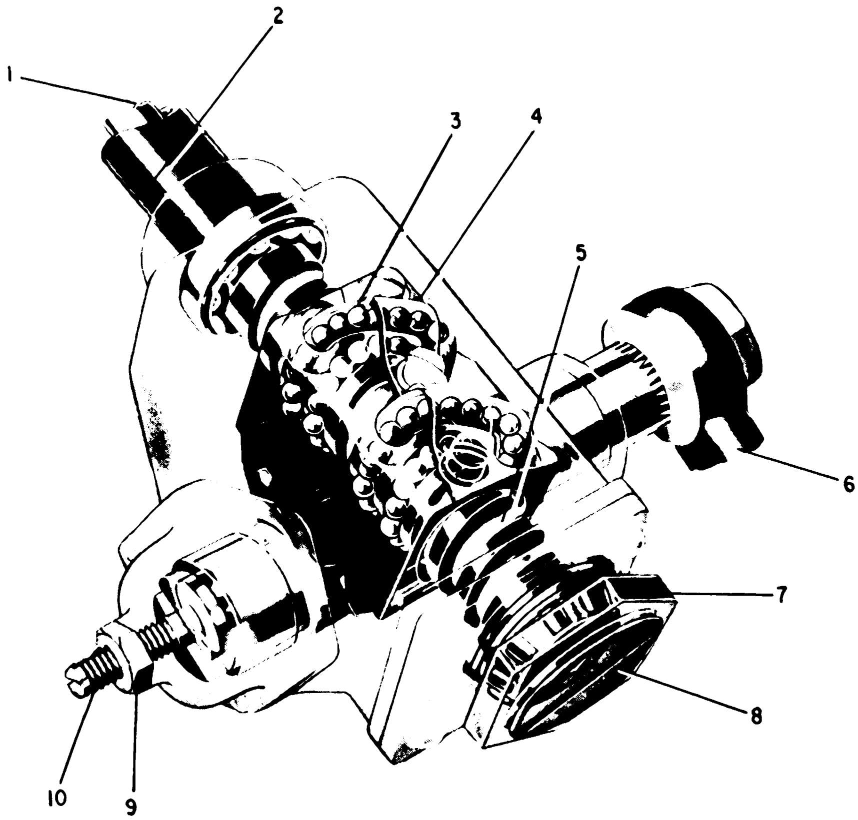
Figure 16-11.—Steering gear unit—cam and lever type.

operate on the same principle as the worm gear and sector.

In the cam and lever type of steering gear unit, the cam is mounted on the lower end of the steering shaft, and the lever is mounted on the cross shaft. As the steering gear is turned, the studs on the lever are engaged with the cam and are moved up and down on the cam. The lever moves with the studs. The cross shaft moves with the lever and moves the pitman arm, which in turn moves the steering linkage.

A somewhat different type of steering gear is shown in figure 16-12. In this unit, friction is kept exceptionally low by interposing balls between the major moving parts, or between the worm gear teeth and the grooves cut in the inner face of a ball nut. The rotation of the worm gear causes the balls to roll in the worm teeth. The balls also roll in the grooves cut in the inner face of the nut. Thus, as the worm rotates, the balls cause the nut to move up and down along the worm. This up-or-down motion is carried to the gear sector by teeth on the side of the ball nut. This then forces the gear sector to move along with the ball nut so that the pitman arm shaft rotates.

The balls are called recirculating balls because they can continuously recirculate from one end of the ball nut to the other through a pair of ball return guides. For example, assume that the driver makes a right turn. The worm gear is rotated in a clockwise direction (viewed from the driver's seat) and this causes the ball nut to move upward. The balls roll between the worm and ball nut, and as they reach the upper end of the nut, they enter the return guide and then roll back to a lower point



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1. Steering gear shaft.
2. Jacket
3. Recirculating balls.
4. Ball nut.
5. Worm.
6. Pitman arm.
7. Worm bearing adjusting screw lock nut.
8. Worm bearing adjusting screw.
9. Lash adjuster screw lock nut.
10. Lash adjuster screw.

Figure 16-12.—Steering gear unit—recirculating ball type.

where they reenter the groove between the worm and ball nut.

On equipment that is steered by the rear wheels, the steering components and operation are the same except that a longer drag link is necessary to permit the driver to face forward. Because the steering column must be pointed forward to permit the operator to face forward, the distance from the gear case and pitman arm to the steering knuckle arm is greater than on a front wheel steering vehicle. Thus, a longer drag link is required. More and more support equipment is being equipped with rear wheel steering mechanisms, especially those designed for aircraft carrier operation.

POWER STEERING

Most of the newer types of self-propelled support equipment are equipped with power steering. This takes most of the effort out of steering and, therefore, makes it easier for the operator to maneuver such equipment as tow tractors, weapons loaders, etc. This is especially important for equipment used on aircraft carriers where maneuvering space is limited.

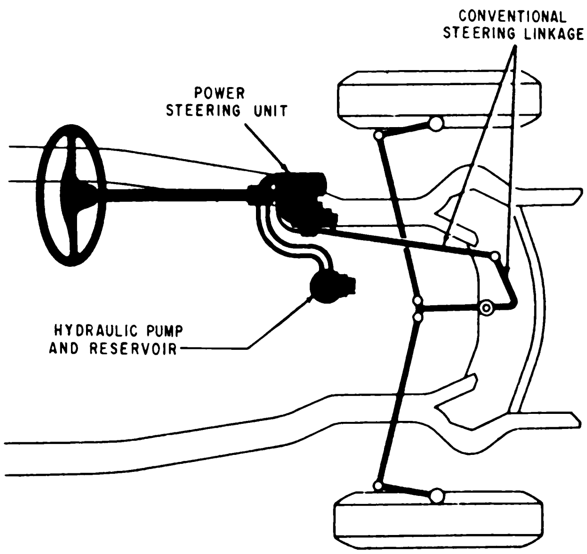

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Figure 16-13.—Diagram of a power steering unit.

The principle of power steering is very simple. A booster arrangement is provided which is set into operation when the steering wheel is turned. The booster then takes over and does most of the work of steering. Compressed air and electrical mechanisms have been used in power steering; however, hydraulic pressure is used on the vast majority of power steering mechanisms today.

Automotive hydraulic power steering systems consist of three basic components—the pump (including a reservoir), the power cylinder or cylinders, and the control valve. The power steering pump is driven by the engine or an engine-driven accessory by a belt, gears, or a shaft. Lines and hoses connect the three units. All systems are constructed in such a manner that the vehicle can be steered manually, should the power steering system fail.

In one type of power steering the power cylinder and the control valve are built into the gear case at the base of the steering column. As the steering wheel is turned to the right or left, the control valve directs hydraulic fluid pressure to one side or the other of a piston in the power cylinder. The power cylinder is connected to the pitman shaft and, therefore, turns the pitman arm accordingly. When the driver returns the steering wheel to the neutral or straight ahead position, the pressure on both sides of the piston is equalized and the vehicle travels straight ahead. The pump is usually adjacent to a fluid reservoir where the excess hydraulic fluid is stored. A diagram of this

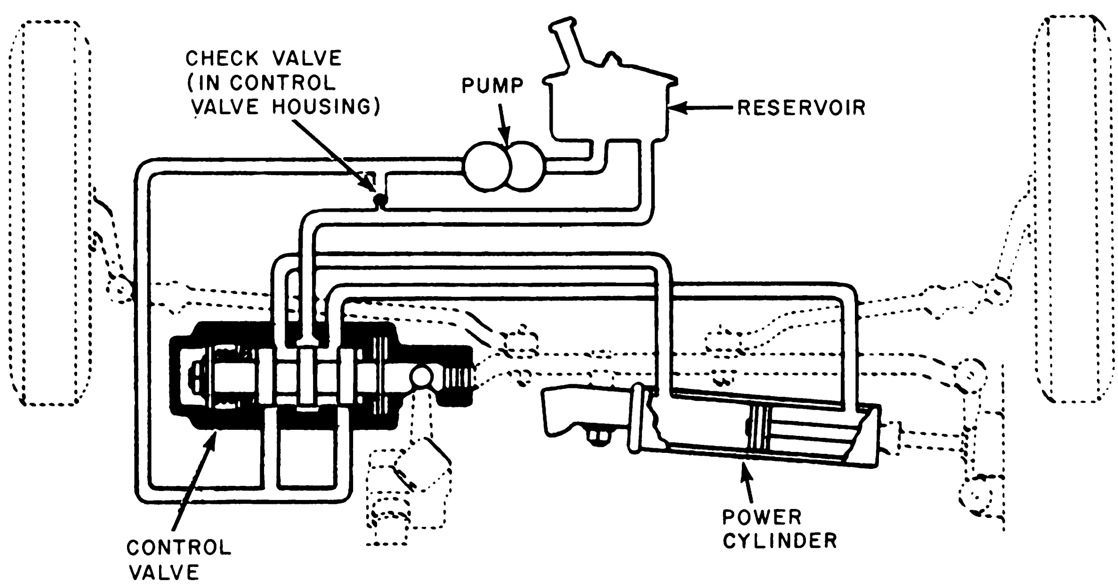

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Figure 16-14.—Power steering system.

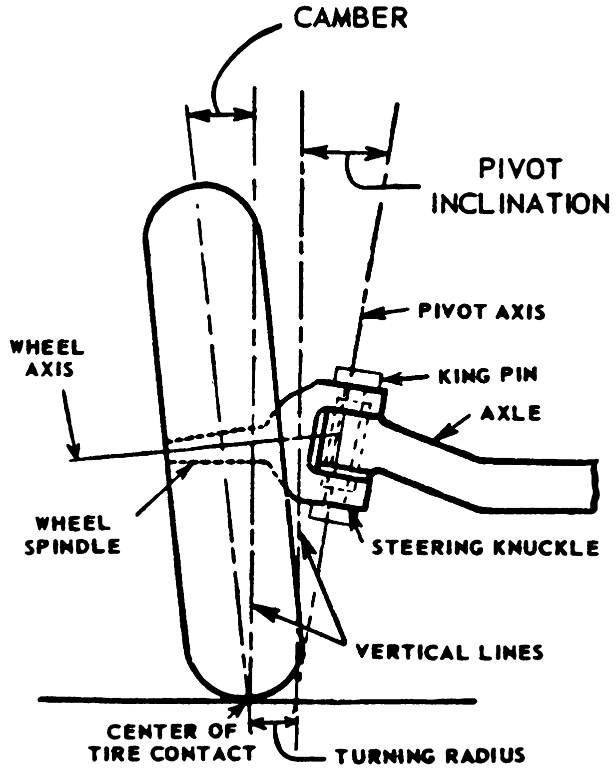

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Figure 16-15.—Pivot inclination and camber.

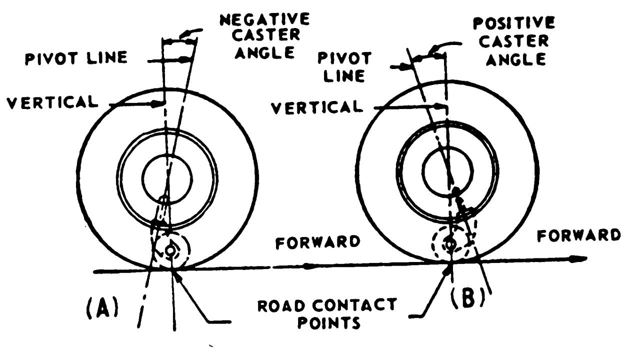

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Figure 16-16.—Negative and positive caster.

type power steering system is illustrated in figure 16-13.

In the other type of power steering system, the control valve is located on the pitman arm

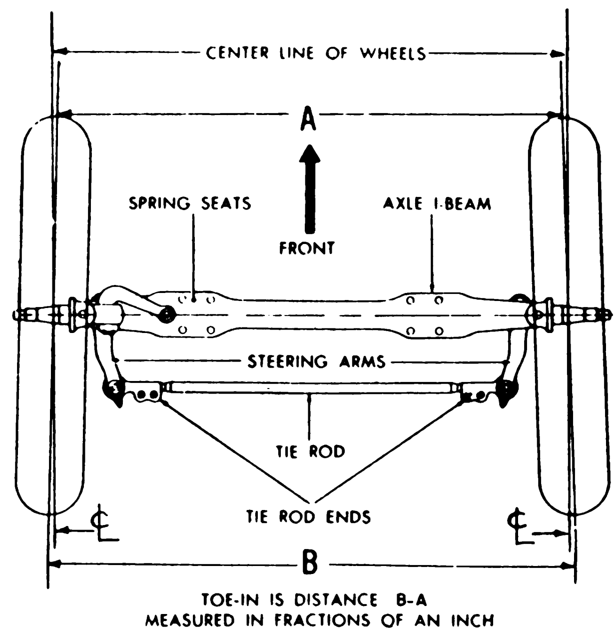

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Figure 16-17.—Toe-in.

at the base of the steering column. The power cylinder is mounted on the tie rod between the wheels. A system of this type is illustrated in figure 16-14.

When the steering wheel is turned, the pitman arm turns and changes the position of the control valve. This routes fluid under pressure to one side of the cylinder, which assists in turning the wheels. When the steering wheel is in neutral, equal pressure is applied to both sides of the power cylinder. Therefore, the wheels remain in the straight ahead position.

WHEEL ALIGNMENT

Steering control depends, to a great extent, upon the position of the wheels in relation to the rest of the vehicle and the surface over which it travels. Any changes from the specified setting of the wheels affect steering and the riding control of the vehicle. Therefore, the proper wheel and steering alignment is important for vehicle control.

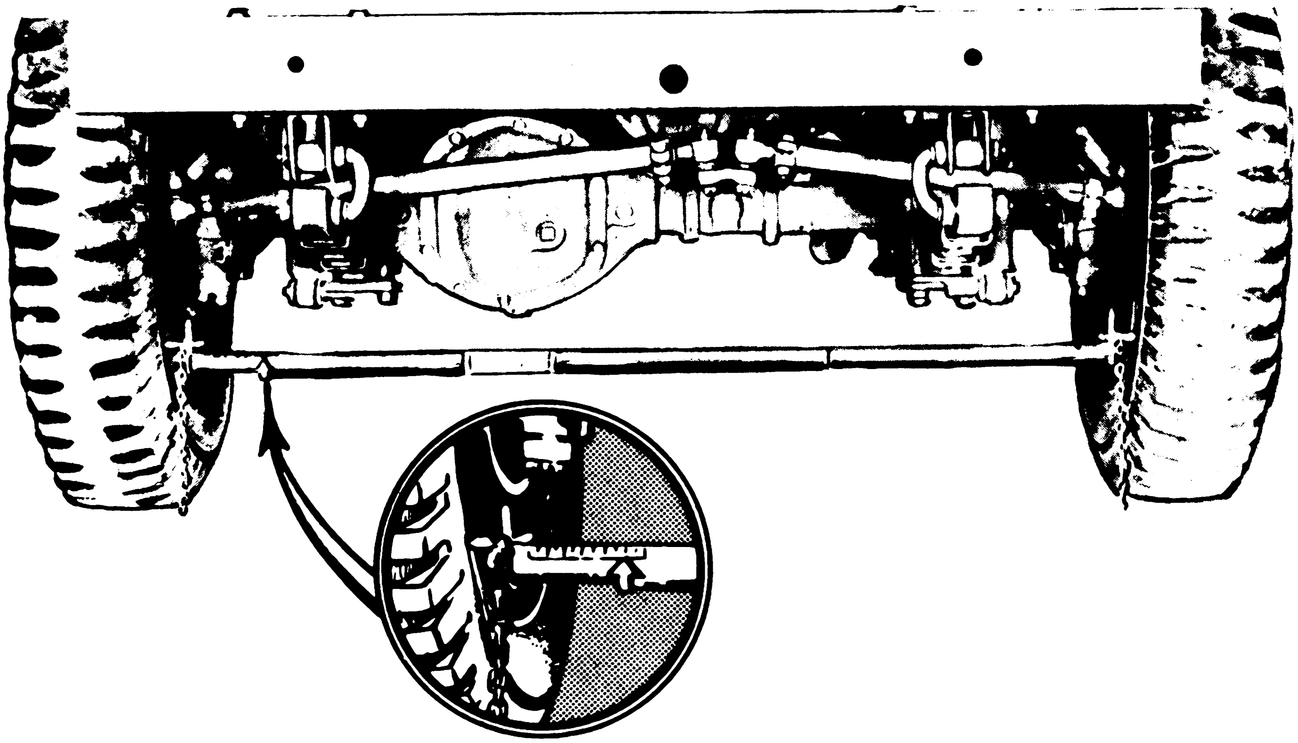

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Figure 16-18.—Checking toe-in with a measuring pole.

Front End Geometry

Front end geometry is the term manufacturers use to describe steering and front wheel alignment. This includes pivot inclination, wheel caster, wheel camber, toe-in, and toe-out. These terms refer to angles in the front wheel alignment which may change because of driving over rough terrain, striking stationary objects, accident damage, and normal wear.

Pivot inclination (sometimes referred to as kingpin angle) (fig. 16-15) is the number of degrees that the kingpin is tilted toward the center of the vehicle from a vertical position. Pivot inclination keeps the wheel spindles pointed outward and in line with the axle, and helps to make steering easier.

Camber (fig. 16-15) is the number of degrees that the wheels are tilted in or out at the top. Wheels having camber are closer together at the bottom than they are at the top. Camber, together with pivot inclination, reduces side thrust on the kingpin bearings in the steering knuckle and support, thus permitting easier steering and less wear of parts. The camber angle in most of the late model vehicles seldom exceeds 1 degree and is obtained by tilting the wheel spindles slightly downward on the steering knuckles. Camber brings the wheels perpendicular to the surface of the ground, permitting better rolling contact. In modern vehicle design, greater pivot inclination reduces the need for excessive camber.

Caster is the number of degrees that the steering knuckles are tilted to the rear, or to the front. Caster tends to keep the front wheels pointed straight ahead and brings them back to the straight forward position after a turn. The front wheel of a bicycle is castered and permits the rider to steer without using his hands. When the castered wheel of the bicycle is turned from the straight ahead position by leaning sideways, the front end is raised slightly. After the turn is made, the weight of the bicycle forces the front end down and helps straighten the wheel.

In vehicles equipped with leaf type springs, caster is obtained by inserting wedges or shims

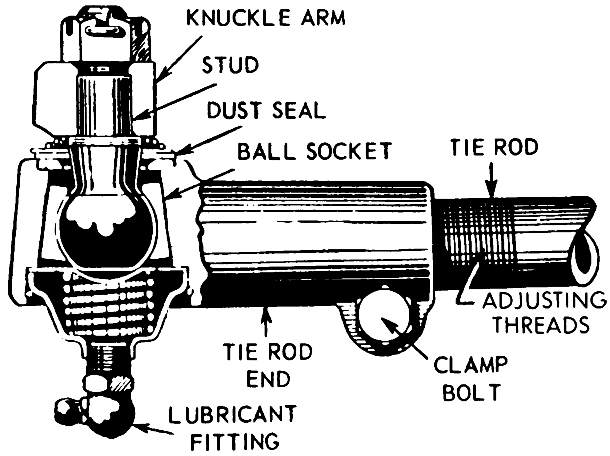

Figure 16-19.—Tie rod end showing clamp bolt and adjusting threads.

between the front axle and the spring so that the steering knuckle pivots are tilted slightly backward from the vertical. Most modern vehicles do not have leaf type springs. On this type vehicle, shims are placed between the upper suspension arm and the frame to obtain the desired caster.

If the knuckle pivots (kingpins) are tilted forward, the caster is said to be negative. (See fig. 16-16.) The caster is said to be positive when the knuckle pivots are tilted backward. Most vehicles have negative caster; however, some modern vehicles have positive caster. Caster is measured in degrees and varies from approximately 1/2 degree to approximately 3 degrees on modern vehicles.

Wheels that have camber must also have toe-in. Toe-in (fig. 16-17) is the fraction of an inch that the front wheels point in toward the vehicle. When forced to follow a straight path by motion of the vehicle, cambered wheels tend to slip away from each other. In contrast, toe-in wheels tend to travel toward each other and, therefore, balance the effect of camber.

Toe-out refers to the difference in angles between the two front wheels and the vehicle frame. Since the inner wheel rotates on or follows a smaller radius than the outer wheel when the vehicle is rounding a curve, its axle must be at a sharper angle with the frame; that is, it must toe out more. Toe-out is a design feature of the steering geometry for which there is no required adjustment.

Maintenance and Adjustment

The operator can often detect steering and alignment troubles. For example, he can detect hard steering or play in the steering system. However, the cause of such malfunctions must be located and corrected by repair and/or adjustment.

Some steering wheel play is normal and provides for easier steering of the vehicle. A large amount of play, however, means a freer movement of the steering wheel without a corresponding movement of the front wheels. Excessive wheel play is caused by improper adjustment or wear of the steering linkage, steering knuckle parts, or loose wheel bearings. Worn or improperly adjusted linkage connections can be checked by jacking up the front end of the vehicle, grasping both front wheels, and pulling in on both at the same time, to check for excessive movement. At the same time, checks for worn knuckle parts and loose wheel bearings can be made by grasping the top and bottom of each wheel and shaking to determine the amount of wobble.

The steering gear can be checked by watching the pitman arm while someone turns the steering wheel one way and then the other. If considerable movement of the steering wheel is required to set the pitman arm in motion, the steering gear is either worn or out of adjustment.

Hard steering may be caused by very tight adjustments or mechanical difficulties in the steering gear or linkages, not enough air in the tires, or improper wheel alignment.

Sometimes the operator may say that the vehicle "wanders." This may be the result of oversteering. Nevertheless, the vehicle should be checked for low tire pressures, improper wheel alignment, and tight or loose wheel and brake adjustments. "Pulling" of the vehicle when applying the brakes could be caused by grabbing brakes. If the vehicle "pulls" when driven, the toe-in and toe-out should be checked, in addition to the other causes already mentioned.

Steering shocks, caused by sharp and rapid movements of the steering wheel, may be the result of driving over a rough surface or hitting objects on the surface. When the vehicle does

not steer properly, it should be checked for sagging springs, defective shock absorbers, or looseness in the steering gear or linkage. Uneven tire inflation also could be the cause.

If floating turn tables are available, they should be used to check steering errors. After the vehicle is driven onto the tables, the front wheels should be turned with the steering wheel. Each floating table will turn with the wheel on it and register the angle of the turn. When the turning angle of one wheel (the outer wheel while making a turn) is 20 degrees, the turning angle of the opposite (inner) wheel should be approximately 23 degrees. This difference is the toe-out.

Before checking front wheel alignment, the front tires should be checked for proper inflation, and the steering knuckles and linkages, shock absorbers, and wheel bearings should be checked for proper adjustment. A number of devices may be used for testing wheel alignment. One of these, the wee-gee board, consists of a metal plate fastened at one end and free to sideswing on supporting balls. This board measures the sideslip of the tire. When the vehicle is driven over the board, watch the indicator as the board moves. If the indicator moves toward the center of the vehicle, the wheels need more toe-in. On the other hand, if the indicator moves away from the center of the vehicle, the wheels have too much toe-in. The wee-gee board is not considered to be a very accurate or reliable device for measuring wheel alignment but may be used when none of the more accurate measuring devices are available.

Another device for measuring toe-in is the measuring pole. (See fig. 16-18.) Each pole has a pointer and a gage on one end and can be lengthened and shortened in a manner similar to that of a curtain rod.

With the vehicle resting on a level floor and the wheels in the straight ahead position, push the vehicle forward a few feet to remove all play in the axle assembly. Place pencil marks on the inside walls of the tires at equal distances from the floor, and at both the front and rear of the tires.

Place the pole between the two marks at the front of the tires and set the pointer at zero. Then, use the pole to measure the distance between the two marks on the rear of the tires. The distance between the two rear marks should conform to the manufacturer's specifications. If not, the toe-in should be adjusted.

The length of the tie rod is adjusted to increase or decrease the toe-in. In figure 16-18, the right-hand tie rod is adjusted for the proper setting. Figure 16-19 shows a cross section of one end of the tie rod attached to the knuckle arm.

Before making any adjustments, count the number of exposed threads at the ends of the tie rod. One end of the tie rod has a right-hand thread and the other a left-hand thread. Turning the rod in one direction so that more of these threads enter the fitting will shorten the rod. Turning the rod in the opposite direction will expose more threads and, therefore, lengthen the rod. Very little turning is required for proper toe-in adjustment.

To increase or decrease toe-in, loosen the clamp bolts and turn the rod in the direction which results in the proper adjustment. Use a pipe wrench and make one turn at a time. If the tie rod is behind the axle, a longer tie rod will increase toe-in and a shorter tie rod will decrease toe-in. If the tie rod is in front of the axle, a longer tie rod will decrease toe-in, and a shorter tie rod will increase toe-in. Always tighten the clamp bolts after making an adjustment.

Caster and camber may also be checked with the wee-gee board. If the two front wheels do not register the same reading, the caster and camber of one or both of the wheels are incorrect. On some vehicles, both caster and camber are adjusted by turning the upper arm pivot with an Allen wrench or a special offset wrench. The appropriate technical manual should be consulted for correcting caster and camber on other vehicles.

CHAPTER 17

CORROSION PREVENTION AND CONTROL

The reliability and effectiveness of support equipment depend largely upon the structural soundness of the metals which make up the largest percentage of their many parts. One great threat to structural integrity of the many items of support equipment is metal corrosion. Each item of support equipment may be used in a variety of climatic and atmospheric conditions. These conditions range from the hot dry desert to the hot humid tropics to the cold arctic regions. In addition, the equipment is most often used in the salt filled atmosphere near many shore bases, on islands, and especially on aircraft carriers. These are some of the environmental conditions which vary the speed and intensity of metal corrosion.

Corrosion changes the mechanical characteristics and thereby reduces the strength of a material. Materials are designed to carry certain loads and withstand given stresses as well as to provide an extra margin of strength for safety. Corrosion can weaken the structure thereby reducing or eliminating this safety factor. Replacement or reinforcement operations are costly, time-consuming, and reduce usage of the equipment. Severe corrosion can cause failure of parts or systems. Such malfunctions can cause an important item of equipment to become inoperative during very critical demands. This reemphasizes the importance of corrosion control.

The ASH must know the types and applications of corrosion prevention and moisture protecting materials. To accomplish this he must be familiar with the types and causes of corrosion, types and uses of cleaning materials, materials and procedures for preservation and depreservation, and the means for the detection of corrosion. This information is described in the first part of this chapter. The last part of the chapter is devoted to painting, which is the most common and perhaps the most effective means of preventing most types of corrosion.

CORROSION

Metal corrosion is the deterioration of metals as they combine with oxygen to form metallic oxides. This combining is a chemical process which is essentially the reverse of the process of smelting the metals from their ores. Very few metals occur in nature in the pure state. For the most part they occur naturally as metallic oxides. The oxides may also be mixed with other undesirable impurities in the ores. The refining process generally involves the extraction of relatively pure metal from its ore and the addition of other elements (either metallic or nonmetallic) to form alloys. As discussed in chapter 6, alloying constituents are added to base metals to develop a variety of useful properties.

After refining, regardless of whether or not alloyed, base metals possess a potential or tendency to return to their natural state. However, potential is not sufficient in itself to initiate and promote this reversion. There must also exist a corrosive environment, in which the significant element is oxygen. It is the process of oxidation—combining with oxygen—that causes wood to rot or burn and metals to corrode.

Control of corrosion is dependent upon maintaining a separation between susceptible alloys and the corrosive environment. This separation is accomplished in various ways. A good intact coat of paint provides almost all of the corrosion protection on support equipment. Sealants are used at seams and joints to prevent entry of moisture, and preservatives are used on unpainted surfaces. Tarpaulins, covers, caps, and other mechanical equipment provide varying degrees of protection from corrosive media. None of these, however, provides 100-percent protection. Paint is subject to oxidation and decay through weathering; sealants may work out by vibration or else be eroded by rain and wind. Preservatives at best offer only temporary protection when used on operating equipment and the mechanical coverings are subject to improper installation and neglect.

Control of corrosion properly begins with an understanding of the causes and nature of this

phenomenon. Corrosion is caused by electrochemical or direct chemical reaction of metal with other elements. In the direct chemical attack, the reaction is similar to that which occurs when acid is applied to bare metal. Corrosion in its most familiar form is a reaction between metal and water and is electrochemical in nature.

In the electrochemical attack, metals of different potential are involved and they need not be in direct contact. When one metal contains positively charged ions and the other negatively charged ions and an electrical conductor is bridged between them, current will flow as in the discharge of a dry cell battery. In electrochemical corrosion, the conductor bridge may be any foreign material such as water, dirt, grease, or any debris that is capable of acting as an electrolyte. (Electrolyte is a nonmetallic conductor in which current is carried by the movement of ions.) The presence of salt in any of the foregoing mediums tends to accelerate the current flow and hence speed the rate of corrosive attack.

Once the electrical couple is made, the electron flow is established in the direction of the negatively charged metal (cathode), and the positively charged metal (anode) is eventually destroyed. All preventive measures taken with respect to corrosion control are designed primarily to avoid the establishment of the electrical circuit, or secondly, to remove it as soon as possible after establishment before serious damage can result. Figure 17-1 illustrates the electron flow in a corrosion environment (electrolyte) resulting in destruction of the anode area. Note that the surface of a metal, especially alloys of the metal, may contain anode and cathode areas due to impurities or alloying constituents which have different potentials than the base metals.

Electrochemical attack is evidenced in several forms, depending upon the metal involved, its size and shape, its specific function, atmospheric conditions, and the type of corrosion-producing agent (electrolyte) present. There are many forms of metal deterioration resulting from electrochemical attack about which a great deal is known. But despite extensive research and experimentation, there is still much to be learned about other more complex and subtle forms. Descriptions are provided later in this chapter for the more common forms of corrosion which may be found on the various metals of ground support equipment.

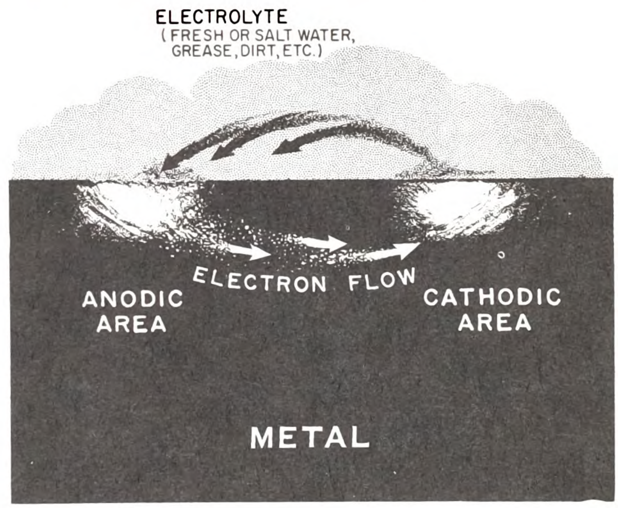

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Figure 17-1.—Simplified corrosion cell.

Since there are so many factors which contribute to the process of corrosion, selection of materials by the equipment manufacturer must be made with required properties and qualities, such as hardness, malleability, elasticity, strength, etc., as the primary consideration, and corrosion-resistant properties as the secondary consideration. However, close attention during equipment design and production is given to heat treating and annealing procedures, protective coatings, choice and application of moisture barrier materials, dissimilar metals contact, and access doors and plates. In other words, every logical protection is taken by the equipment manufacturers to prevent the onset and spread of corrosion attack.

There are many factors that affect the type, speed, cause, and seriousness of metal corrosion. Some of these corrosion factors can be controlled; others cannot. Preventive maintenance factors such as inspection, cleaning, painting, and preservation are within the control of the maintenance activity. They offer the most positive means of corrosion deterrence.

The electrochemical reaction which causes metal to corrode is a much more serious factor under wet, humid conditions. The salt in sea water and the salt in the air is the greatest single cause of corrosion of ground support

equipment. Hot climates speed the corrosion process because the electrochemical reaction develops most rapidly in a warm solution, and warm moisture in the air is usually sufficient to start corrosion if the metals are not coated. As would be expected, hot dry climates usually provide relief from constant corrosion problems. Extremely cold climates produce corrosion problems if a salt atmosphere is present. Melting snow or ice provides the necessary water to begin the electrochemical reaction.

APPEARANCE OF CORRODED PARTS

One of the problems involved in corrosion control is recognizing corrosion products when they occur. The following paragraphs include brief descriptions of typical corrosion product characteristics of the more common materials of support equipment construction.

Iron and Steel

Possibly the best known and easiest recognized of all forms of metal corrosion is the familiar reddish colored iron rust. When iron and its alloys corrode, dark iron oxide coatings usually form first, and these coatings, such as heat scale on steel sheet stock, may protect iron surfaces rather efficiently. However, if sufficient oxygen and moisture are present, the iron oxide is soon converted to hydrated ferric-oxide, which is the conventional red rust.

Aluminum

Aluminum and its alloys exhibit a wide range of corrosive attack, varying from general etching of aluminum surfaces to penetrating attacks along the internal grain boundaries of the metal. The corrosion products of aluminum are seen as white to gray powdery deposits.

Magnesium and Its Alloys

Magnesium corrosion products are white and quite large compared to the size of the base metal being corroded. The deposits have a tendency to raise slightly and the corrosion spreads rapidly. When white puffy areas are discovered on magnesium it requires prompt attention as the corrosion may penetrate entirely through the structure in a very short time.

Copper and Copper Alloys

Copper and its alloys are generally corrosion resistant, although the products of corrosion attack on copper are commonly known. Sometimes copper or copper alloy surfaces will tarnish to a dull gray-green color and the surface may still be relatively smooth. This discoloration is the result of the formation of a fine-grained, airtight copper oxide crust, called a patina. This patina in itself offers good protection for the underlying metal in ordinary situations. However, exposure of copper and copper alloys to moisture or salt spray will cause the formation of blue or green salts indicating active corrosion. These salts will form over the patina since the crust is not moistureproof. Copper alloys used in support equipment have a cadmium-plated finish to prevent surface staining and deterioration.

Cadmium and Zinc

Cadmium, particularly, is used as a coating to protect the part to which it is applied and to provide a compatible surface when the part is in contact with other materials. The cadmium plate supplies protection to the underlying metal because of its greater activity. That is, during the time it is protecting the base metal, the cadmium is intentionally being consumed. It functions in the same way that an active magnesium rod inserted in the water system protects the piping of a hot water heater. The cadmium becomes an anode and is attacked first, leaving the base metal free of corrosion.

Zinc coatings are used for the same purpose. Attack is evident by a white to brown to black discoloration of the surfaces. These indications DO NOT indicate deterioration of the base metal. Until the characteristic colors peculiar to corrosion of the base metal appear, the cadmium or zinc is still performing its protective function. Wire brushing or removal of the stained areas of the cadmium or zinc merely reduces the amount of cadmium or zinc remaining to protect the underlying structure.

Nickel and Chromium Alloys

These metals are also used as protective agents, both in the form of electroplated coatings and as alloying constituents with iron or stainless steels. Nickel and chromium plate

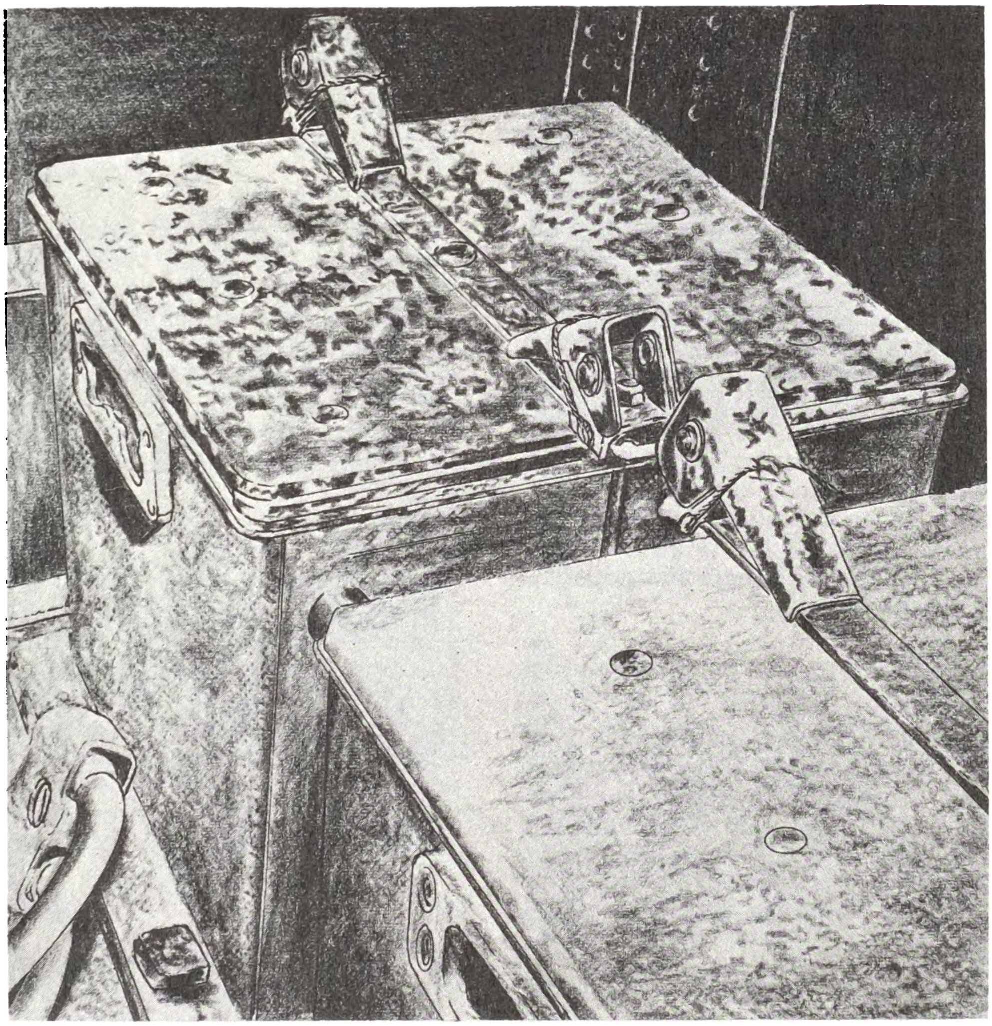

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Figure 17-2.—Direct surface attack in battery compartment.

protect by forming an actual physical noncorrosive barrier over the steel. Electroplated coatings, particularly chromium on steel, are somewhat porous, and corrosion eventually starts at these pores or pinholes unless a supplementary coating is applied and maintained.

FORMS OF CORROSION

As previously stated, corrosion may occur in several forms, depending upon the metal involved, its size and shape, its specific function, atmospheric conditions, and corrosion-producing agents present. Those described in this section are the more common forms found on the various metals of ground support equipment. Corrosion has been cataloged and typed in many ways. For description purposes, the types are discussed here under what is considered the most commonly accepted titles.

Uniform Etch Corrosion

This form is so named because it appears as a general etching of the exposed surface

areas. It results from direct reaction of metal surface with oxygen in the air. General attack also occurs under marine conditions from exposure of bare metal to salt spray or salt-bearing air. In industrial areas, similar attack takes place from the presence of sulfur and chlorine compounds in industrial gases. The same type of attack results when the metal surfaces are exposed to solid particles and gases blown from the exhausts of aircraft carriers, aircraft, and automotive equipment. An extreme example of surface attack is the battery compartment illustrated in figure 17-2. These surfaces were exposed to acid spillage or fumes.

The surface effect produced by most direct chemical attacks is a uniform etching of the metal. On polished surfaces this type of corrosion is first seen as a general dulling of the surface. If such corrosion is allowed to continue, the surface becomes rough and possibly frosted in appearance.

Pitting Corrosion

The most common effect of corrosion on aluminum and magnesium alloys is called pitting. It is first noticeable as a white or gray powdery deposit, similar to dust, which blotches the surface. When the deposit is cleaned away, tiny pits or holes can be seen in the surface. Pitting corrosion may also occur in other types of metal alloys.

Intergranular Corrosion

Intergranular corrosion is an attack on the grain boundaries of a material. The granular structure of a metal consists of quantities of individual grains, and each of these tiny grains has a clearly defined boundary which chemically differs from the metal within the grain center. The adjacent grains of different elements can react with each other as anode and cathode when in contact with an electrolyte (conductive medium). Rapid corrosion at the grain boundary can then occur.

Intergranular corrosion may exist without visible evidence on exterior surfaces. It develops so gradually that it is well established before becoming apparent, and serious structural weakening may occur before an appreciable volume of corrosion products accumulate on the surface. Some of the methods used for detecting intergranular corrosion are described later in this chapter under Inspection of Metals.

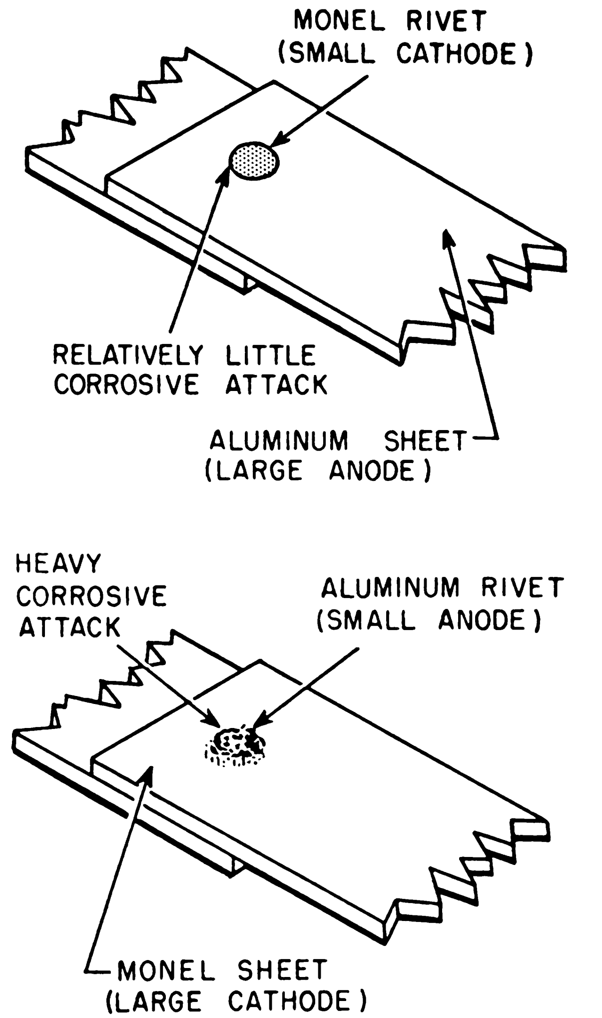

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Figure 17-3.—Effects of area relationships in dissimilar metal contacts.

Exfoliation Corrosion

Exfoliation is a form of intergranular corrosion and shows itself by lifting up the surface grain of a metal by the force of expanding corrosion products occurring at the grain boundaries just below the surface. It is visible

evidence of intergranular corrosion and is most often seen on extruded sections where grain thicknesses are usually less than in rolled forms.

Dissimilar Metals Corrosion

Dissimilar metals corrosion, or galvanic corrosion, occurs when dissimilar metals are in contact and an external circuit is provided by the presence of moisture. It is usually recognized by the presence of a buildup of corrosion at the joint between the metals. For example, aluminum and magnesium metals riveted together form a galvanic couple if moisture and contamination are present. When aluminum pieces are attached with steel bolts or screws, galvanic corrosion can occur between the aluminum and the steel.

When such a condition develops, either from faulty design or from maintenance errors, the most easily oxidized surface becomes the anode and corrodes. If the more active member of the two metals is small compared to the less active member, attack will be severe and extensive when insulation breaks down. If the area of the less active metal is small compared to the other, the attack is relatively slight. Figure 17-3 illustrates this factor.

Stress Corrosion

Stress corrosion, evidenced by cracking (fig. 17-4), is the result of the combined effect of static stresses applied to a surface over a period of time under corrosive conditions. Distorted and stressed metal tends to become anodic when in contact with stress-free material, and galvanic attack occurs along the lines of stress, which in turn results in rapid failure of the part. Press and shrink fits, pipe thread type fittings, clevis joints, and exposed or overstressed tubing nuts are examples of parts susceptible to stress corrosion cracking.

Fatigue Corrosion

Fatigue corrosion is a special kind of stress corrosion and is caused by the combined effects of corrosion and stresses applied in cycles to a part. Resulting corrosion usually starts at the bottom of an existing shallow pit in the stressed area. Sharp deep pits form and become the origin of cracks that may ultimately result in part failure. This type of attack is

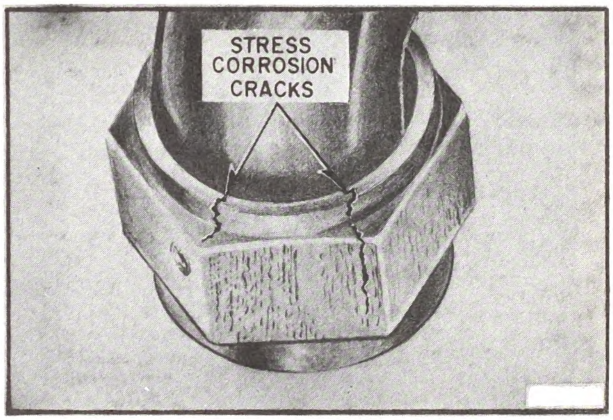

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Figure 17-4.—Stress corrosion cracking.

characteristic of any part under regular cyclic stressing. An example of cyclic stress is the alternating loads to which the reciprocating rod on the piston of a hydraulic, double-acting actuating cylinder is subjected. During the extension stroke a compression load is applied and during the retracting or pulling stroke, a tensile or stretching load is applied.

Once fatigue corrosion begins, continuous flexing prevents repair of protective surface coatings, and additional corrosion takes place in the area of stress. This is difficult to detect in advance, except as cracking develops. Frequently, by the time it is noticed, the only solution is replacement of the part.

Fretting Corrosion

Fretting corrosion is a limited but highly damaging type of corrosion caused by a slight vibration, friction, or slippage between two contacting surfaces which are under stress and heavily loaded. It is usually associated with machined parts, such as the area of contact of bearing surfaces, two mating surfaces, and bolted or riveted assemblies. At least one of the surfaces must be metal.

In fretting corrosion, the slipping movement at the interface of the contacting surface destroys the continuity of the protective films that may be present on the metallic surface. This action removes fine particles of the basic metal. The particles oxidize and form abrasive

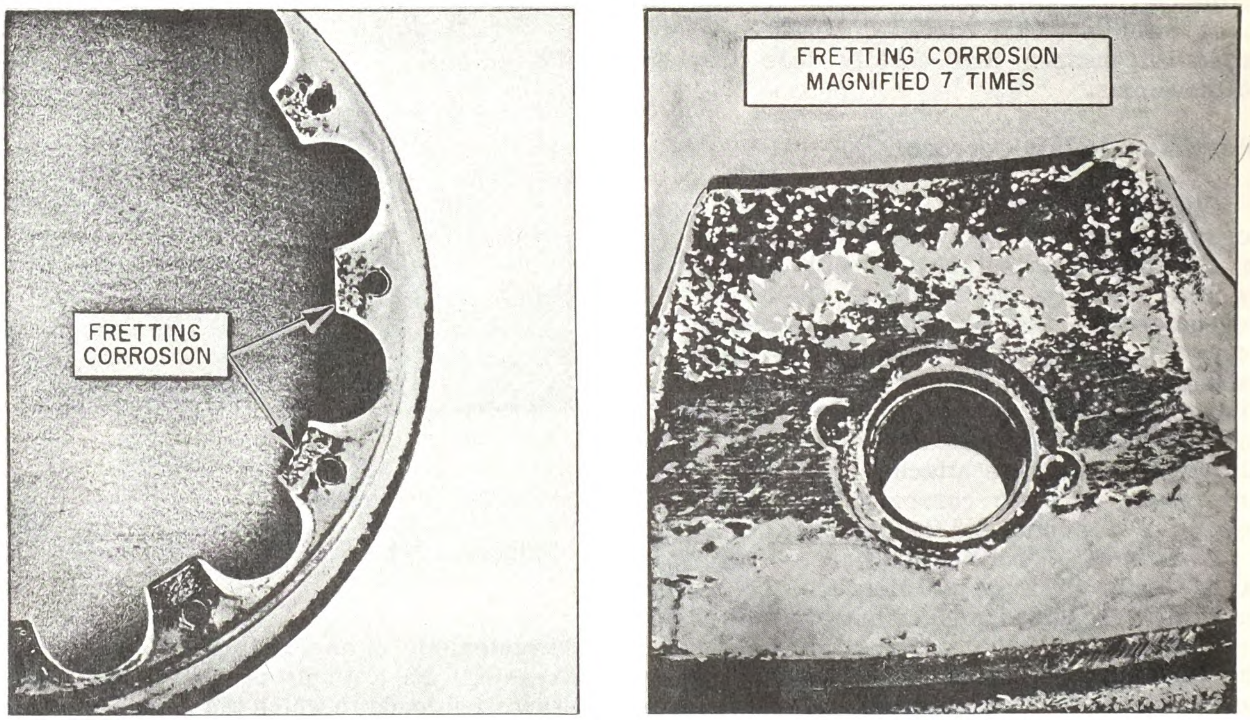

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Figure 17-5.—Fretting corrosion.

materials which further agitate within a confined area to produce deep pits. Such pits are usually so located as to increase the fatigue potential of the metal.

Figure 17-5 shows an example of fretting corrosion. This type of corrosion is evidenced at an early stage by surface discoloration and by the presence of corrosion products in any lubrication present. Lubrication and securing the parts so that they are rigid are the most effective measures to prevent this type of corrosion.

Filiform Corrosion

Filiform corrosion is threadlike filaments of corrosion known as underfilm. Metals coated with organic substances, such as paint films, may undergo this type of corrosion.

Filiform corrosion occurs independent of light, metallurgical factors in the steel, and bacteria, but takes place only in relatively high humidity (65 percent and above). Although the threadlike filaments are visible only under clear lacquers or varnishes, they also occur with some frequency under opaque paint films. Filiform corrosion can occur on steel, zinc, aluminum, magnesium, and chromium plated nickel.

Microbiological Corrosion

Micro-organisms contained in sea water can be introduced into fuel systems by contaminated fuel. These fungus growths attack any sealing material that might be used in fuel tanks. Under certain conditions, they can cause corrosion of aluminum by aiding in the formation of concentration cells. Residues resulting from biological growth tend to clog fuel filters and coat capacity probes, giving erroneous fuel quantity readings.

PREVENTIVE MAINTENANCE

Preventive maintenance is a powerful tool which can be used to effectively correct even the most difficult corrosion problems. The intensity of such a program will vary to meet the severe environment of shipboard operations, and the relatively mild conditions of an inland shore base.

Preventive maintenance, as related to corrosion control, includes the following specific functions:

1. An adequate cleaning program.
2. Periodic lubrication.
3. Detailed inspection for corrosion and failure of protective systems.
4. Emergency treatment of corrosion as it occurs.
5. Early paint touchup of damaged areas.
6. Use of supplementary preservative coatings as necessary.
7. Adequate draining of internal cavities by maintaining drain holes free of obstructions.
8. Daily wipedown of exposed critical surfaces such as the reciprocating portions of hydraulic cylinders.
9. Use of available protective covers when equipment is not in use.

One of the biggest problems in corrosion control is in knowing what materials to use, where to find them, and the limitations applicable to their use. Materials used should be those covered and controlled by military specifications. Corrosion control information pertaining to materials, methods, and techniques is scattered throughout many directives and instructions, and this information is constantly being revised as better chemicals and protective methods are developed. The following is a list of sources of information that should be readily available to the personnel performing maintenance on ground support equipment. Although the contents of these publications are intended for the prevention and control of corrosion on aircraft and weapons systems, most of the information is adaptable for ground support equipment.

1. Aircraft Cleaning and Corrosion Control for Organizational and Intermediate Levels, NA 01-1A-509.
2. Preservation of Naval Aircraft, NA 15-01-500.
3. Chart—Chemical Materials for Naval Weapons Systems—Maintenance and Overhaul Operations, NA 07-1-503.
4. Chart—Corrosion Preventive Compounds for Protection of Naval Weapons Systems, NW 01-1A-518.
5. Periodic Maintenance Requirements Cards (as applicable). In addition, many of the Instructions Manuals for support equipment contain information concerning the cleaning and preservation of the specific item of equipment and/or its components.

SURFACE MAINTENANCE

Surface maintenance includes regular cleaning of the equipment as well as touchup of protective paint coatings. Since paint touchup is accomplished after removal of corrosion, coverage on this subject is included under the heading, Corrosion Elimination, later in this chapter. This does not imply that touchup of damaged paint should not be done unless corrosion is present. Touchup of new damage to paint finishes will prevent corrosion from starting there.

The cleaning of support equipment is an important function not only to maintain the appearance, but for the safe and efficient operation of the equipment. In keeping with this importance, acceptable materials, methods, and procedures must be used for the cleaning of the equipment. Instances of serious damage have resulted to exterior and interior of items of support equipment due to lack of correct information regarding materials and equipment and their use. Shipboard procedures are not necessarily the same as procedures ashore, but the same materials are available and comparable results are accomplished, although different application methods may be necessary.

How often an item of equipment shall be cleaned depends on several factors, such as the type of equipment, its location, and its use. It is important that support equipment be maintained in a clean condition, and cleaning should be accomplished as often as required. Equipment must be thoroughly cleaned before being placed in storage and should also receive a thorough cleaning at the time of depreservation. Aboard ship, cleaning and removal of salt deposits are necessary as soon as practicable to prevent corrosion. Components and parts which are exposed to corrosive environments, such as engine exhaust gas or acid, are cleaned as often as may be required to minimize exposure to these corrosive agents.

NOTE: Lubrication and preservation of exposed components are necessary to displace any of the cleaning solution entrapped during the cleaning operation.

Materials

Only approved cleaning materials should be used on support equipment. Navy specification cleaning materials are made up and compounded to accomplish definite results and are made available only after complete testing and actual field maintenance. All specification materials are inspected and tested before acceptance and delivery to the supply activities.

Cleaning agents commonly used for cleaning of support equipment are included in the following categories.

SOLVENTS.—Solvents are liquids which dissolve other substances. There are a great number of different solvents, but for cleaning purposes, organic solvents are most often used. Some solvents are chlorinated. When solvents contain more than 24 percent by volume of chlorinated materials they must be kept in specially marked containers and care must be taken to insure that equipment on which these solvents are used are designed and operated as to prevent the escape of such solvents, as a liquid or vapor, into the workroom.

All personnel occupied with or working near chlorinated solvents should be particularly careful to avoid breathing the vapors. While the vapors from some solvents are more toxic than others, prolonged breathing of the fumes can be injurious to health.

In addition to the breathing hazard associated with solvents, they also present varying degrees of fire and explosion hazards, depending upon the material. It is considered that solvent cleaners having a flashpoint greater than 105°F are relatively safe. Those having flashpoints below 105°F require explosion proofing of equipment and other special precautions when using them. (The flashpoint is the temperature at which the first flash from the material is seen, as an open flame is passed back and forth over a sample.)

Another hazard associated with solvents, and to a certain extent with all cleaning materials, is the effect on the surface or material being cleaned. Some solvents will deteriorate rubber, synthetic rubber, asphaltic coverings, etc. This is such an important consideration that it must always be taken into account when selecting cleaning materials. It may do a good job in removing dirt, grease, oil, etc., but may also damage the object being cleaned or soften and ruin otherwise good paint coatings.

Solvent, Drycleaning.—This material is a petroleum distillate commonly used for support equipment cleaning. It is furnished in two types, I and II. Type I material, commonly known as Stoddard solvent, has a flashpoint slightly above 105°F. Type II has a higher (safer) flashpoint and is intended for shipboard use.

In Support equipment maintenance, Stoddard solvent (type I) is used as a general all-purpose cleaner for metals, painted surfaces, and fabrics. It may be applied by spraying, brushing, dipping, and wiping.

Mineral Spirits.—This is another liquid petroleum distillate which is used as an all-purpose cleaner for metal and painted surfaces, but is not recommended for fabrics. Like Stoddard solvent, it may be applied by spraying, brushing, dipping, and wiping.

Aromatic Naphtha.—This is a petroleum aromatic distillate. This naphtha is a bare-metal cleaner and is also used for cleaning primer coats before applying lacquer. It will remove oil, grease, and light soils. It is also highly flammable and reasonably toxic. CAUTION: Do not use aromatic naphtha on acrylic surfaces as it will cause crazing.

Safety Solvent.—Methyl chloroform is intended for use where a high flashpoint and less toxic solvent is required. It is used for general cleaning and grease removal of assembled and disassembled engine components in addition to spot cleaning, but should not be used on painted surfaces. Safety solvent is not suitable for oxygen systems although it may be used for other cleaning in ultrasonic cleaning devices. It may also be applied by wiping, scrubbing, or booth spraying. The term "safety solvent" is derived from the high flashpoint and is easier to say and remember than methyl chloroform.

Aliphatic Naphtha.—This is an aliphatic hydrocarbon product used as an alternate compound for cleaning acrylics and for general cleaning purposes that require fast evaporation and no remaining film residue. It may be applied by dipping and wiping. Saturated surfaces must not be rubbed vigorously, as it is a highly volatile and flammable solvent with a flashpoint below 80°F. This solvent is reasonably toxic; therefore, prolonged contact with the skin or prolonged breathing of the vapors

should be avoided. It should be used in well-ventilated spaces only.

Thinner, Cellulose Nitrate Dope and Lacquer.—Although this material is intended for use as a thinner for dope and lacquer, it may also be used for the removal of oil, grease, and light soils from bare metal. This solvent is applied with wiping rags or soft bristle brushes over small areas at a time.

Methyl-Ethyl-Ketone (MEK).—This material is used as a cleaner for bare-metal surfaces. It is applied with wiping cloths or soft bristle brushes over small areas at a time.

EMULSION CLEANERS.—Emulsion cleaners differ from solvent cleaners in their action on contaminants to be removed. With solvents, the contaminants go into solution with the cleaning materials. Emulsion cleaners tend to disperse contaminants, except sand, etc., into tiny droplets which are held in suspension in the cleaner.

Emulsion cleaners must be used with precautions since some are flammable and toxic and, like solvents, may damage paint or other finishes.

Cleaning Compound, Solvent, Grease Emulsifying, Type I.—This is a liquid emulsifying agent containing soap and solvent. It is nonphenolic. (See Type II which follows.) This compound is used for exterior cleaning, cleaning installed engines, all painted surfaces (metal and wood), and bare metal. It is a heavy duty cleaner for removal of oil, grease, atmospheric films, industrial films, mud, sand, and soils of all types. It is also used for removal of paralketone and similar corrosion preventive compounds.

Both types (I and II) of this compound must be mixed with Stoddard Solvent or mineral spirits prior to use. A ratio of 1 part compound to 4 to 9 parts of solvent is recommended. Heavier soils require the heavier concentration. The heavy concentrations clean best when the ambient temperature is high.

For best results this compound should be sprayed on the dry surface and then brushed thoroughly. Moist or water-wetted surfaces reduce the emulsion action. It can be used for hand wipedown, or hand scrubbing on small areas. Regardless of the method of application, the emulsion compound and loosened soil should be thoroughly flushed away with high-pressure water.

Cleaning Compound, Solvent, Grease Emulsifying, Type II.—This is a liquid emulsifying compound containing phenolic materials. (Phenolic materials are obtained from the distillation of many organic substances such as wood, coal, etc., and from coal tar. The popular name for the phenols is carbolic acid.) Due to the acid content and type of cleaning for which designed, its use is very limited. Type II cleaning compound is designed for the heaviest, toughest cleaning jobs, but its acidity renders it harmful to many support equipment materials.

Cleaning Compound, Water Emulsion.—This is a liquid emulsifying agent containing soap and water. This compound is used in solution with 10 to 15 parts water for the heavy-duty removal of oil, grease, industrial films, mud, sand, and soils of all types. This material is applied by spray or brush to cold, wet surfaces, brushed lightly and after a 5-minute dwell time, thoroughly flushed with water.

SOAPS AND DETERGENT CLEANERS.—There is a variety of materials available in this category for mild cleaning use. In this section, only some of the more common materials are discussed.

Cleaning Compound, Detergent, Type I (powder) and Type II (liquid).—These compounds are used in the general cleaning of painted and unpainted surfaces for the removal of light-to-medium soils, operational films, oils, and grease. They are safe to use on all surfaces, including fabrics, leather, and transparent plastics.

The Type I is used in a water solution containing 1 to 4 ounces of compound per gallon. The concentration of Type II in a water solution may be varied from 0.1 to 1.5 percent by weight. The concentration of either type depends upon the nature of the soil encountered. This solution is to be used as a hand wash and cleaner. Washing should be performed in the shade whenever possible, first cooling the surface to be cleaned with cold water. The surface should be rinsed immediately after cleaning to prevent the compound from drying hard on the surface.

Cleaning Compound, Waterless.—This cleaning compound is intended for use on painted and unpainted surfaces in heavy-duty cleaning operations under conditions where water for rinsing is not readily available or when freezing temperatures do not permit the use of water. It is a relatively nontoxic, noncorrosive, stable, nonflowing gel, and its detergent properties enable it to serve as an agent for the removal of grease, tar, wax, carbon deposits, and exhaust stains. This cleaner is applied with a dampened

cloth or sponge except in freezing weather when a dry applicator should be used.

MECHANICAL CLEANING MATERIALS.—Mechanical cleaning materials such as abrasive papers, polishing cloths, wools, wadding, etc., are available in the supply system as needed. However, their use must be in accordance with directions supplied with the materials if damage to the finishes and surfaces is to be avoided.

Aluminum Oxide Paper.—Aluminum oxide paper (300 grit or finer) is available in several forms and is safe to use on most surfaces since it does not contain sharp or needlelike abrasives which can embed themselves in the base metal being cleaned or in the protective coating being maintained. The use of carborundum (silicon carbon) papers should be avoided. The grain structure of carborundum is sharp, and the material is so hard that individual grains can penetrate and bury themselves even in steel surfaces.

Powder Pumice.—This material is similar to Bon Ami, which may also be used. The pumice is used as a slurry with water and is applied to the surface with clean rags and bristle brushes.

Impregnated Cotton Wadding.—Cotton which has been impregnated with a cleaning material is used for the removal of exhaust gas stains and for polishing corroded aluminum surfaces. It is also used on other metal surfaces to produce a reflectance.

Lacquer Rubbing Compound, Type III.—For the removal of engine exhaust residues and minor oxidation, lacquer rubbing compound, Type III, may be used. Heavy rubbing over rivet heads or edges where protective coatings may be thin should be avoided as the coverings may be damaged most easily at these points.

CHEMICAL CLEANERS.—Chemical cleaners must be used with great care in cleaning assembled equipment. The danger of entrapping corrosive materials in between layers of metal and at seams counteracts any advantages in their speed and effectiveness. All materials used must be relatively neutral and easy to remove. It is important that all residues from this type cleaning be removed. Soluble salts from chemical surface-treatment such as chromate acid or dichromate treatment will liquify and promote blistering in the paint coatings.

Phosphoric-Citric Acid Mixture.—This chemical surface cleaner is available in two types, I and II. Type I is a ready-to-use prepackaged mixture. Type II is a concentrate which must be diluted with mineral spirits or water as required. The mixture is applied to the surface to be cleaned with a soft brush, rag, or sponge, using a circular brushing motion in order to loosen the surface film. After a 15-minute dwell time, this acid mixture should be thoroughly flushed from the cleaned surface with a stream of water.

Bicarbonate of Soda.—This material, commonly known as baking soda, should always be available to neutralize acid deposits as well as to treat acid burns from chemical cleaners and inhibitors. It can also be used to clean tarnished silver contacts by placing the silver-coated part in contact with magnesium metal and submerging the two in a solution of baking soda and salt.

Cleaning Equipment

The cleaning of ground support equipment not only requires the use of correct cleaning materials, but also the use of proper cleaning equipment to produce efficient and satisfactory results. A specific cleaning area should be prepared and equipped for performing cleaning operations.

The choice of cleaning equipment depends upon several factors, such as the amount of cleaning that is regularly performed, the type of support equipment that is being cleaned, the location of the activity, and the availability of facilities such as air, steam, and electricity.

Some of the specialized equipment available for cleaning support equipment consists of pressure tank sprayers, high-pressure cleaning machines, and industrial vacuum cleaners. In some cases this equipment can be manufactured locally by the activity, otherwise it is procured through regular supply channels.

In addition to the specialized equipment mentioned above, other items such as hoses, spray guns, brushes, sponges, and wiping cloths are required for cleaning the equipment. These items are procured through regular supply channels.

Items for personal protection such as rubber gloves, rubber boots, goggles, and aprons should be worn when necessary to protect the clothing and eyes from fumes and splashing of the caustic materials.

Cleaning Methods and Procedures

The first step in cleaning an item of support equipment is to select the proper cleaning agent for the method of cleaning to be used. For some items of equipment, the recommended type of cleaning agent for each method and instructions and precautions to be observed in their use may be found in the applicable Instructions Manual. If this information is not included in the applicable manual, the instructions on the container of the cleaning agent must be followed.

The next step is the preparation of the item of equipment for cleaning. This step, of course, will vary with the type, size, and model of equipment. The item of equipment should be placed in a cool shady place if possible. Most items of equipment should be grounded to the deck during cleaning. Cleaning operations cause buildup of static electricity, which is dissipated through the ground wire. After securing all the obvious openings such as access panels, further secure the equipment against entry of water and cleaning compounds. In addition, mask or otherwise cover all equipment or components that can be damaged by moisture or the cleaning agent being used.

WATER WASH CLEANING.—The water wash method is recommended as the most efficient and satisfactory method of cleaning most items of support equipment when it is only lightly contaminated with dirt and grease. The item of equipment is prepared as previously outlined, and all cleaning materials and equipment that will be required during the cleaning operation should be on hand and ready for use. Prior to beginning the actual wash, the entire item of equipment should be wet down. The equipment is then washed using the prescribed cleaning solution and sponges or soft cloths.

After each step in the water wash procedure, the cleaning solution should be rinsed off with clean water. All cleaning solution must be removed from joints, recesses, and other possible places where it can collect. Surfaces are dried with clean sponges or soft cloths if necessary.

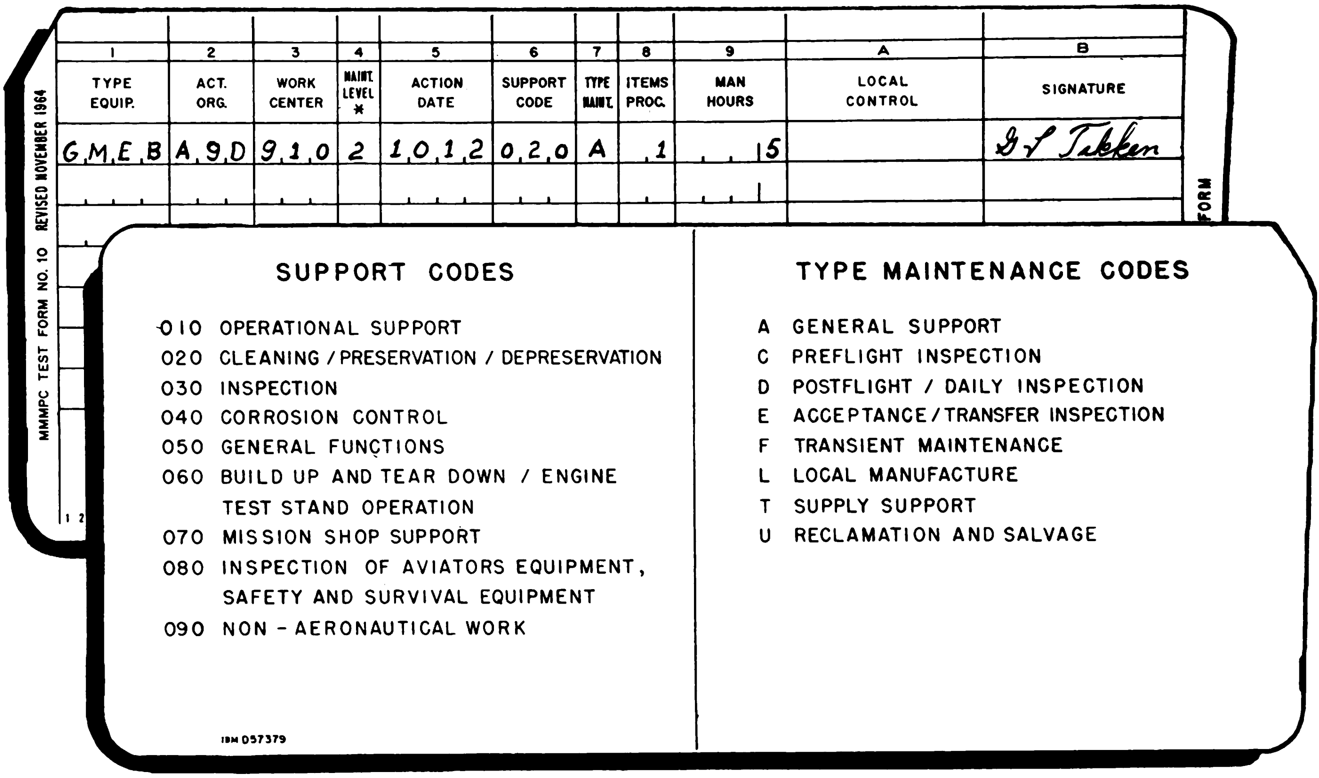
EMULSION CLEANING.—The emulsion cleaning method is used to clean areas contaminated with oil, grease, or other foreign matter which cannot be easily removed by other methods. The item of equipment is prepared the same as for the water wash method. Mix the emulsion in accordance with the Instructions Manual for the type equipment concerned or the instructions on the emulsion container. The emulsion solution is applied to either wet or dry surfaces depending upon the type emulsion. If it is the type that must be applied to wet surfaces, the surface should first be dampened with warm water. After application of the emulsion solution, a dwell time of 5 minutes is usually sufficient to loosen all contaminants. Rinse the area with high-pressure hot or cold water. If any areas are still not clean, repeat the operation as necessary on these areas only. Finally the surface is dried with a clean sponge or cloth. This is important after emulsion cleaning as air-drying may leave the paint coatings streaked, especially if the surfaces were not adequately rinsed.

STEAM CLEANING.—High-pressure, live steam and a suitable steam cleaning compound will remove the majority of soils with a minimum of manhours and time. With this method, one of several types of steam generating machines must be used. The types, operation, and maintenance of steam cleaners are covered in chapter 10 of this manual.

Steam cleaning is a harsh cleaning method that is very effective when expertly accomplished, but can severely damage components and painted surfaces if improperly done. Extreme care should be exercised when using steam or hot water. The nozzle should be held at an angle of 45 degrees to the surface being cleaned. The distance the nozzle is held from the surface depends upon the finish. In addition, the nozzle should never be held in one place too long or local overheating may result, causing damage to the components or surfaces of the equipment. It is necessary to provide cover protection for plastics, seals, and other materials which can be damaged by this cleaning method. Some manufacturers do not recommend the use of steam on painted surfaces.

Figure 17-6 illustrates the documentation of a Support Action Form (SAF) for the time spent cleaning an item of support equipment. The spaces 1 through 9 and A and B are self-explanatory and should be filled in accordingly. For detailed instructions on the SAF and its uses, consult Military Requirements for Petty Officers 3 & 2, NavPers 10056-C, chapter 14, or OpNav Instruction 4790.2 (Series).

NOTE: Since the cleaning of support equipment is within the labor code of an ASH assigned to the support equipment work center in



MMMPC TEST FORM NO. 10 REVISED NOVEMBER 1964

1	2	3	4	5	6	7	8	9	A	B
TYPE EQUIP.	ACT. ORG.	WORK CENTER	MAINT. LEVEL *	ACTION DATE	SUPPORT CODE	TYPE MAINT.	ITEMS PROC.	MAN HOURS	LOCAL CONTROL	SIGNATURE
GMEB	A9D	910	2	1012	020	A	1	15		G S Tekken

SUPPORT CODES

010 OPERATIONAL SUPPORT
020 CLEANING / PRESERVATION / DEPRESERVATION
030 INSPECTION
040 CORROSION CONTROL
050 GENERAL FUNCTIONS
060 BUILD UP AND TEAR DOWN / ENGINE TEST STAND OPERATION
070 MISSION SHOP SUPPORT
080 INSPECTION OF AVIATORS EQUIPMENT, SAFETY AND SURVIVAL EQUIPMENT
090 NON - AERONAUTICAL WORK

TYPE MAINTENANCE CODES

A GENERAL SUPPORT
C PREFLIGHT INSPECTION
D POSTFLIGHT / DAILY INSPECTION
E ACCEPTANCE/TRANSFER INSPECTION
F TRANSIENT MAINTENANCE
L LOCAL MANUFACTURE
T SUPPLY SUPPORT
U RECLAMATION AND SALVAGE

IBM 057379

AS.771

Figure 17-6.—SAF documentation for cleaning an item of support equipment.

an Intermediate maintenance activity, a Manhour Accounting (MHA) card is not required for this action, unless it is performed after normal working hours, on a Saturday, Sunday, or holiday.

USE OF COVERS AND SHROUDS

Many types of support equipment, when delivered by the manufacturer, are equipped with a complete set of tailored dust and protective covers. These covers and shrouds should be installed in such a manner that free drainage is assured. Do not create a bathtub which will trap and hold water. Shrouds or covers may also act as a greenhouse in warm weather and cause collection and condensation of moisture underneath. The shroud should be loosened or removed and the equipment ventilated on warm sunny days. Where protection from salt spray is required aboard carriers, the covers should be left in place and the equipment ventilated only in good weather. Fresh water condensation will do far less damage than the entrapped salt spray.

In emergencies where regular waterproof canvas covers are not available, suitable covering and shrouding may be accomplished by using polyethylene sheet, polyethylene coated cloth, or metal foil barrier material, all of which are available in the Navy supply system. These covers should be held in place with adhesive tapes designed specifically for severe outdoor application. The tapes are also available in supply.

GENERAL HANDLING

There are many commonsense practices which should be observed to minimize paint damage and the loss of built-in protective systems during operation and maintenance of support equipment.

Painted surfaces will withstand a normal amount of abrasion by air lines, fuel hoses, etc. However, these items pick up bits of sand, gravel, and metal chips and become a coarse abrasive which scratches and scuffs the protective finish to the point where it is rendered completely ineffective under shipboard

operating conditions. Dropping tools, toolboxes, etc., on the surface also chips and cracks the paint.

When removing access plates during inspections the removed hardware should not be placed on the deck to blow around and become scratched. It is not practical to provide pads or cushioning for these components, but they should at least be secured to prevent their movement. When using power tools or handtools to remove and install screws and when using handtools to fasten and unfasten quick-disconnect fasteners, particular care should be taken to avoid scratching the paint. (NOTE: Power tools must not be used to fasten and unfasten quick-disconnect fasteners.) Five minutes of extra time spent in careful use of tools will save 5 hours of paint touchup and corrosion removal work later.

PRESERVATION AND DEPRESERVATION

The susceptibility of support equipment to corrosion damage is greatest during those periods when the equipment is dirty, inactive, or being shipped. For this reason, the equipment must be preserved during storage, shipment, or during long maintenance and repair periods.

Suitable protection against corrosion attack is achieved essentially by placing a barrier between the cleaned surface that is to be protected and any possible source of moisture. During manufacture or overhaul of support equipment, protective barriers such as electroplate, paint, or chemical surface treatment are provided. Surfaces that cannot be so treated, and in some instances the treated surfaces themselves, must be covered with special corrosion-preventive compounds. The protection these compounds give is effective only if no moisture, dirt, or active corrosion is present on the treated surface. It is essential, therefore, that the items of support equipment be thoroughly clean and dry before a preservative compound is applied. It is also necessary that an unbroken film of preservatives be applied in as moisture-free an atmosphere as practicable.

Compounds alone do not provide complete protection. Tapes, barrier paper, and sealing devices must also be used to seal off any openings on the equipment which, if allowed to remain open during longtime storage, would permit the entry of moisture and dirt. To provide additional protection against corrosion a complete moisture barrier is sometimes provided. Internal areas that have been sealed off are dehydrated by installing desiccants (moisture absorbents) to remove entrapped moisture unless the cavity is protected with a vapor corrosion inhibitor. When any area cannot be sealed adequately, provisions must be made for ventilation and moisture drainage.

In maintenance of support equipment, preservation means supplementing the protection already present, or providing temporary protection to damaged areas, by the use of various protective coatings and barrier materials. A brief description of some of the more common materials used in ground support equipment preservation and readily available in Navy stock is included in the following paragraphs.

Compound, Corrosion-Preventive, Solvent Cutback

This material is familiarly known as "paralketone." It is supplied in four grades for specific application. All grades of this compound may be applied by brush, dip, or spray. They may be easily removed with Stoddard Solvent or mineral spirits. These materials are designed for cold application. Some preservative compounds must be applied hot; therefore, when intending to use one of the grades of this solvent cutback material, the specification number should always be verified.

Grade 1 forms a dark hard-film, opaque cover. Its general use is limited because of the difficulty in removing aged coatings and also because of the hiding power of the material when it is applied over corroded areas. This material is used only where maximum protection against salt spray is required.

Grade 2 is a soft-film, grease-type material that can be used on most operating parts. Its chief disadvantage is the fact that it may be washed off under direct exposure to salt water or may be removed by inadvertent wiping. It protects under relatively severe conditions and, given adequate maintenance and touchup as necessary, can be used for most maximum protection requirements.

Grade 3 is a very light, water-displacing preservative, with the ability of penetrating under surface water and forming a protective film on the metal. This material is most effective in treatment of equipment or components after direct exposure of critical surfaces to water. This grade offers only limited protection

for short periods of time and must be supplemented by frequent maintenance or heavier materials as soon as practicable.

Grade 4 preservative forms thin, semitransparent films through which identification data can usually be read. It also sets up relatively dry to the touch so that preserved parts may be easily handled. This grade has proved particularly effective in protecting exposed areas where film transparency is required and moderate protective characteristics can be tolerated. The main disadvantage of this material is that it is easily removed by water spray and requires replacement at frequent intervals under severe exposure conditions.

Corrosion-Preventive Petroleum

These preservatives are designed for hot application and are available in two classes—Class 1 (hard film) and Class 3 (soft film). Both consist of corrosion inhibitors in petroleum. They are removed with Stoddard solvent or mineral spirits. Where a hard film is not necessary, Class 3 should always be used as it is easier to apply and remove yet renders the same degree of protection. Class 1 is generally used for longtime indoor protection of highly finished metal surfaces and cables. Class 3 is used to provide protection of metal surfaces such as antifriction bearings, exposed hydraulic piston rods, and other bright metal surfaces.

Class 1 must be heated to 170° to 200°F before applying by brush or dip. For brushing Class 3 material, it must be between 60° and 120°F and for dipping, between 150° and 180°F.

Oil, Preservative,
Hydraulic Equipment

This oil is used in the preservation of hydraulic systems and components. This oil is similar in appearance to, but is not interchangeable with, operating hydraulic fluid; therefore, before using operating hydraulic fluid (usually MIL-H-5606) or this preservative oil (MIL-H-6083) for any purpose the specification number should be checked to ascertain that the correct oil is being used. The preservative oil contains oxidation and rust inhibitors, viscosity improver, and antiwear agents. Hydraulic parts and components being turned in for screening and repair are flushed and drip drained with MIL-H-6083 oil prior to being forwarded.

Designed primarily for hydraulic components, this oil may be used on any bare critical surface that needs protection. Operating hydraulic fluid will protect a steel panel immersed in water for only about 48 hours. The same metal panel coated with MIL-H-6083 preservative oil will show 100-percent protection for a period of 30 days or more.

Lubricating Oil, General
Purpose, Preservative

There are several different types of lubricating oil, some of which contain preservatives. In order to be absolutely sure that the proper oil is used in a given situation each must be identified with its specification number. The specification number for the oil discussed in this section is VV-L-800 (supersedes MIL-L-644).

VV-L-800 was compounded for lubrication and protection of areas where a water-displacing, low-temperature lubricating oil is required. This oil is highly recommended for use in external piano-type hinges, as it will force out and take the place of any water entrapped between the hinge pin and the tangs.

VV-L-800 may be applied, as received, by brush, spray, or dip methods. It is readily removed with Stoddard solvent or mineral spirits.

Lubricating Oil, General
Purpose, Low Temperature

This is a general purpose oil (specification MIL-L-7870) and is interchangeable with VV-L-800. This oil is suitable for use anywhere that a general purpose lubricating oil with low temperature, low viscosity, and corrosive-preventive properties is required.

This oil is suitable for brush, spray, dip or general squirt-can application. It is not necessary to remove before reoiling or for inspection.

Corrosion Preventive
Compound (MIL-C-23411)

This material is a water displacing corrosion prevention compound and lubricant. It forms a thin, clear protective coating when applied by aerosol, brush, dip, or spray. It offers only short term protection so must be reapplied frequently. On exposed surfaces, protection at its best would be 7 days between applications and

up to 30 days on internal surfaces which are protected from direct outside environments. It is easily removed with drycleaning solvents. It is very effective when used in the following areas: Piano-wire hinges, removable fasteners, B-nuts, linkages, bolts, and nuts, electrical connectors, and micro-switches.

Packaging and Barrier Materials

Packaging and barrier materials are used to seal off critical areas of support equipment during shipment, storage, and during maintenance and repair. These materials are also used to protect removed components when they are sent to overhaul. At least three acceptable barrier materials are available in Navy Stock for these purposes.

WATER-VAPORPROOF BARRIER MATERIAL.—This material is a laminated metal foil barrier that has good water-vapor resistance and can be used for closing of intake openings, for protection of acrylics during cleaning, and for necessary packaging of removed components being returned to overhaul. It is heat sealable with a soldering or clothes iron.

POLYETHYLENE PLASTIC FILM.—This barrier material is used for the same purpose as the metal foil barrier material and is much less expensive. It is, however, not puncture resistant. The plastic film is heat sealable only with special equipment.

POLYETHYLENE COATING CLOTH.—This cloth is used to a great extent for support equipment covers. Its use is preferred over the plastic film material for protective covers because of its greater tear and puncture resistance.

TAPE, FEDERAL SPECIFICATION PPP-T-60, TYPE I, CLASS 1.—This pressure-sensitive tape is used for closure of small openings and for direct contact use on noncritical metallic surfaces. The tape has moderate water-vapor resistance, which is generally adequate for maintenance use. The main disadvantage of this tape is that some cloth-backed materials have not been preshrunk, and tape closures tend to pull loose when exposed to high-humidity conditions.

PRESSURE SENSITIVE ADHESIVE TAPE.—This item is a material developed specifically for exterior preservation and sealing. It is designed for application at temperatures as low as 0°F and should perform satisfactorily over the temperature range from -65°F to 140°F. It is an excellent general purpose tape for exterior preservation and sealing operations.

CORROSION DETECTION

Timely detection of corrosion is essential to any corrosion control program. Of course corrosion can be detected after a part fails, but it is too late to do anything about it other than to intensify inspections of other similar equipment. Inspections for corrosion and deterioration should be a part of all routine inspections. On most types of support equipment there are certain areas that are more prone to corrosion than others. For example, the undersurfaces of vehicles and trailers are very susceptible to corrosion attack. Cables used for control linkages and expecially those used for hoisting must be inspected at regular intervals. Some of the other corrosion prone areas are discussed in the following paragraphs. Reference to the applicable Maintenance Requirements Cards will enable inspections to be amplified and expanded to the necessary degree.

BATTERY COMPARTMENTS AND BATTERY VENT OPENINGS

Fumes from battery electrolyte are difficult to contain and will spread throughout the battery compartment, vents, and even adjacent internal cavities, causing rapid, corrosive attack on unpainted surfaces. (See fig. 17-2.) The external skin area around the vent openings should also be checked regularly for this type corrosion. Corrosion from this cause will continue to be a serious problem whenever batteries are used.

WATER ENTRAPMENT AREAS

These are common trouble spots on many types of support equipment. These areas not only trap water but are natural collection points for waste, hydraulic fluid, dirt, loose fasteners, drill shavings, and other odds and ends of debris. Oil puddles quite often mask quantities of water which settle to the bottom and set up hidden corrosion cells.

Some water entrapment areas are provided with drains. However, in many cases these drains may not be effective, either due to improper location or because they are plugged by sealants, loose fasteners, dirt, and debris.

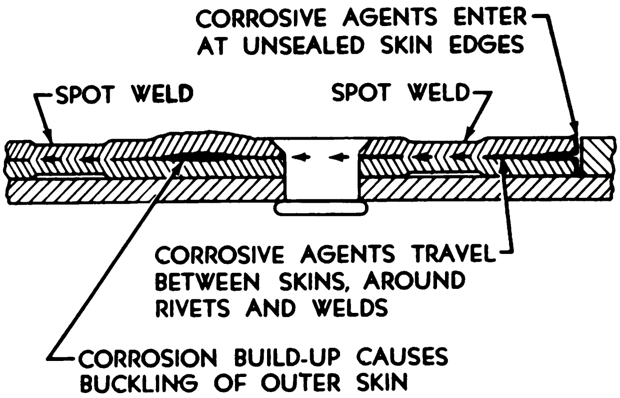


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Figure 17-7.—Spot-welded seam corrosion points.

Daily inspections of these areas and drains should be a standard requirement, especially aboard ship.

EXTERNAL SURFACE AREAS

Most external surfaces of support equipment are covered with protective paint coatings and are readily visible or available for inspection and maintenance. However, seams, edges, areas around fasteners, and cracked, chipped, or missing paint are all corrosion prone areas.

Corrosion of spot-welded seams is chiefly the result of the entrance and entrapment of corrosive agents between the layers of metal. (See fig. 17-7.) Some of the corrosion may be caused originally by fabrication processes, but its progress to the point of skin bulging and spot-weld fracture is the direct result of moisture or salt water working its way in through open gaps and seams. This type of corrosion is first evidenced by corrosion products appearing at the crevices through which the corrosive agents entered. Corrosion may appear at other external or internal faying (closely joined) surfaces, but is usually more prevalent on external surfaces. More advanced corrosive attack causes the metal to buckle and eventually the spot weld to fracture. Buckling in its early stages may be detected by sighting along spot-welded seams or by using a straightedge.

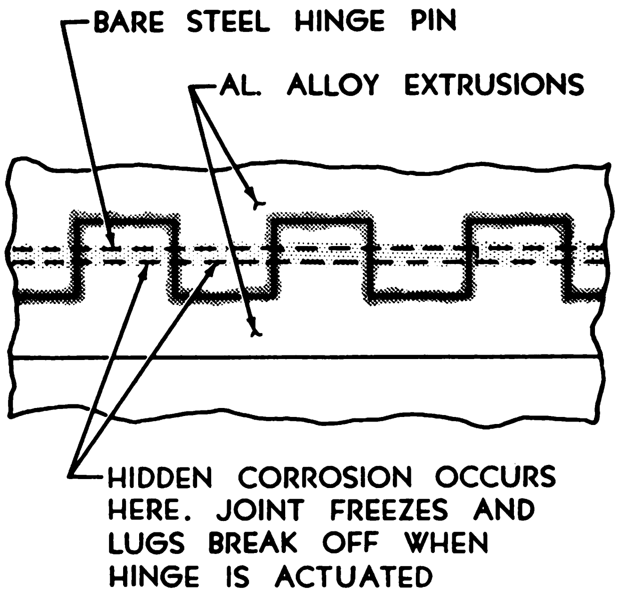

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Figure 17-8.—Hinge corrosion points.

PIANO TYPE HINGES

Piano type hinges are prime spots for corrosion because they are natural traps for dirt, salt, and moisture. In addition, some hinges of this type are constructed of aluminum and hinge on a steel pin, resulting in dissimilar metal contact. (See fig. 17-8.) When this type hinge is used on access doors and plates which are opened only during periodic inspections, they tend to freeze in place between inspections. The inspection for corrosion of these hinges should include lubrication and actuation through several cycles to insure complete penetration of lubricant.

INSPECTION OF METALS

When a metallic part is suspected of having a tiny crack or other invisible defect, it is generally inspected by one of the following methods—the penetrant method, the magnetic particle inspection method, the radiographic (x-ray) method, or the newer eddy current or ultrasonic methods.

The penetrant method is designed for use on nonmagnetic parts such as aluminum, titanium, stainless steel, brass, copper, and cast iron. Metals that can be magnetized (magnetic metals) are inspected by the magnetic particle method. The X-ray method may be used for inspecting any of the foregoing metals. All of these methods are nondestructive tests, which means they are performed on the actual part without damage to the part.

To advance to the E-5 level, the ASH must be able to perform and interpret results of dye penetrant inspections; therefore, major coverage on that subject is provided in this chapter. The coverage on other methods of inspecting metals mentioned above is limited to a brief discussion of each process, as proficiency in these methods is not a requirement for all ASH2's.

PENETRANT INSPECTIONS

Penetrant inspection is a nondestructive test for defects open to the surface in parts made of a nonporous material. Penetrant inspection depends for its success upon a penetrating liquid entering the surface opening and remaining in that opening, making it clearly visible to the operator. It calls for visual examination of the part by the operator after it has been processed, but the visibility of the defect is increased so that it can be detected. Visibility of the penetrating material is increased by the addition of dye which may be either one of two types—visible or fluorescent.

The main disadvantage of penetrant inspections is that the defect must be open to the surface in order to let the penetrant into the defect. For this reason, if the part in question is made of material which is magnetic, the magnetic particle inspection or X-ray is generally recommended. It is also essential that there be no contaminant within the defect which might either prevent the penetrant from entering or reduce its visibility.

The materials used in the visible dye penetrant inspection are available in aviation supply stock in the form of a complete inspection kit. Included in the kit are the following items: spray cans of penetrant, dye remover-emulsifier, and developer. For replenishment purposes, these materials are also available in ordinary containers for use when dipping or brushing is desired.

The fluorescent inspection materials and equipment are also furnished in kit form. The complete equipment is contained in a metallic carrying case. Included are the following items: penetrant, penetrant cleaner, penetrant developer (both powder and suspension types), dauber for applying powder, and a black light assembly complete with power transformer. The chemicals may be replenished individually from aviation supply stock.

General Inspection Procedure

First of all, the part to be inspected must be clean. This includes the removal of surface dirt, scale, paint, and oil, as well as removing any materials or compounds that might fill or cover the defects. If the part has been in contact with water, it may be possible to heat the part slightly to evaporate the water.

Penetrant is then applied to all surfaces. This may be done by dipping, pouring, brushing, or spraying. It is important that all suspect areas be wet with penetrant. The penetrant must be allowed to remain on the part for a period of time called the penetration (dwell) time. This allows the penetrant to seek and fill the surface openings. The length of the penetration time varies with the process and techniques used, the type of material of which the part is made, and the types of defects present.

The excess surface penetrant is removed from the part by means of a forceful water spray. This operation does not remove the penetrant from deep defects but does remove the penetrant from the surface.

The developer is then applied to the part before inspection. The function of the developer is to blot back to the surface the penetrant that is entrapped in fissures or defects in the part. The developer should be allowed to remain in the part for a time before inspection for defects. This elapsed time is to allow the developer to bring back to the surface and magnify the traces of penetrant. Some types of defects in some parts may be detectable without the use of developer; but for consistent and positive results, current instructions recommend that a developer always be used. A drying operation is necessary which increases the effectiveness of the method and, depending upon the type of developer used, either dries the wet developer or prepares the part for the application of the dry developer.

After the proper developing time has elapsed, the part is ready for inspection. If the penetrant used has a fluorescent dye in it, the inspection must be performed in a darkened area and under black light. (A black light is an invisible ultraviolet or infrared light.) If the penetrant used has a visible dye, then inspection can be performed under ordinary lighting conditions.

All traces of the developer should be removed from the part before it is returned to service.

Like all maintenance functions performed on support equipment, a dye penetrant inspection is not considered complete until it has been recorded on the appropriate source document. The circumstances dictate the type of source document required for these inspections. If the inspection is performed in compliance with a technical directive, the Technical Directive Compliance Form (TDCF) is used. A single copy Maintenance Action Form (MAF) is used when a penetrant inspection is performed during scheduled maintenance. In some instances, this type inspection is documented on a Support Action Form (SAF). In other cases, a multicopy MAF is required. OpNav Instruction 4790.2 (Series) should be consulted for information concerning the type document to use for different situations, including the manner in which the required information should be recorded on the specific document.

Types of Processes

There are two basic processes of penetrant inspection—the visible type penetrant and the fluorescent dye penetrant. However, variations of the basic types further divide the processes into seven types. The selection of the process to be used depends on the sensitivity required, the number of parts to be inspected, the surface condition of the part, the configuration of the part, and the availability of water, electricity, compressed air, a suitable area for inspection, and the effect of penetrant chemicals on the material or system being inspected.

The seven types of processes are discussed in the following paragraphs.

TYPE I, SOLVENT-REMOVABLE VISIBLE DYE PENETRANT.—The Type I inspection process uses group I materials which consist of a solvent-removable visible dye penetrant, a penetrant remover (solvent), and a dry, wet, or nonaqueous wet developer. The penetrant is not water-washable, but is removed instead with the solvent penetrant remover.

Following precleaning and drying, the group I penetrant is applied to the surface being inspected by dipping, flow-on, spraying, or brushing methods. After the group I penetrant is allowed to dwell for a predetermined time, it is removed from the surface with the solvent remover, thoroughly dried, and the developer applied. The application of the developer draws out and absorbs the intense red penetrant from the discontinuities to provide indications that should be photographically clear against the white developer background. The indications can be seen in daylight or artificial white light.

The Type I inspection process is used when spot inspection is required, or when water-rinsing is not feasible because of part size, weight, surface condition, lack of water, or remote location.

TYPE II, POST EMULSIFICATION VISIBLE DYE PENETRANT.—The Type II inspection process uses group II materials, which consist of a post emulsifiable visible dye penetrant, an emulsifier, and a dry, wet, or nonaqueous wet developer. The materials used in this process are very similar to that described for the Type III inspection process; however, the penetrants are not self-emulsifiable. An emulsifier is applied over the penetrant to make it water-washable.

Following precleaning and drying, the group II penetrant is applied to the surface being inspected by dipping, flow-on, spraying, or brushing methods. After the group II penetrant is allowed to dwell for a predetermined period of time, the emulsifier is applied. The emulsifier combines with the surface penetrant to make it water-washable. The excess penetrant is washed off, using a low pressure (30 to 40 psi) spray of cold water. The application of developer draws out and absorbs the intense red penetrant from the discontinuities to provide indications that should be photographically clear against the white developer background. The indications can be seen in daylight or artificial white light.

The Type II inspection process is used (1) when inspecting a large volume of parts, (2) a higher sensitivity than group III materials is required or desired, (3) the part is contaminated with acid or other chemicals that will harm water-washable penetrants, (4) discontinuities are wider than their depth, (5) inspecting parts which may have defects that are

contaminated with in-service soils, and (6) inspecting finished surfaces and other general purpose inspections.

TYPE III, WATER-WASHABLE VISIBLE DYE PENETRANT.—The Type III inspection process uses group III materials which consist of a water-washable visible dye penetrant and a dry, wet, or nonaqueous wet developer. The penetrant has self-emulsifying properties to make it water-removable and is of a brilliant red color.

After precleaning and drying, the penetrant is applied to the surface being inspected by one of the four methods described previously, and allowed to dwell for a predetermined period of time. The penetrant is then flushed from the surface using a low pressure (20 to 30 psi) spray of cold water, dried, and the developer applied. The application of the developer draws out and absorbs the intense red penetrant from the discontinuities to provide indications that should be photographically clear against the white developer background. The indication can be seen in daylight or artificial white light.

The Type III inspection process is used (1) when the lowest sensitivity is sufficient to detect the defects inherent to the part, (2) inspecting a large volume of parts, (3) discontinuities are not wider than their depth, (4) surfaces are very rough, (5) inspecting large areas, (6) inspecting threads and keyways, and (7) when the removal of excess penetrant may be difficult due to rough surfaces.

TYPE IV, WATER-WASHABLE FLUORESCENT DYE PENETRANT.—The Type IV inspection process uses group IV materials which consist of a water-washable fluorescent penetrant and a dry, wet, or nonaqueous wet developer. The penetrant has self-emulsifying properties to make it water removable.

After precleaning and drying, the penetrant is applied by one of the four methods described previously and allowed to dwell for a predetermined period of time. The penetrant is then flushed from the surface using a low pressure (20 to 30 psi) spray of cold water, and the developer applied. The penetrant will bleed from the discontinuities or defects into the developer so that flaw indications will become visible when exposed to black light.

The Type IV process is used (1) when inspecting a large volume of parts, (2) discontinuities are not wider than depth, (3) surfaces are very rough, (4) inspecting large areas, (5) the lowest fluorescent penetrant sensitivity is sufficient to detect the defects inherent to the part, (6) removal of excess penetrant may be difficult due to rough surfaces, and (7) sulfonates in emulsifying agents will not affect nickel bearing steels.

TYPES V AND VI POST EMULSIFICATION FLUORESCENT DYE PENETRANT AND SUPERSENSITIVE PENETRANT.—The Types V and VI inspection processes use group V or VI materials. Group V materials consist of a post emulsifiable fluorescent penetrant, an emulsifier, and a dry, wet, or nonaqueous wet developer. Group VI materials consist of the same materials as group V except that the fluorescent penetrant used is more highly sensitive. The materials used in these processes are very similar to those described for the Type IV inspection process; however, these penetrants are not self-emulsifiable. An emulsifier is used to make the penetrant water-washable.

Following precleaning and drying, the group V or VI penetrant is applied to the surface being inspected by one of the four methods described previously and is allowed to dwell for a predetermined period of time. The emulsifier is then applied. The emulsifier combines with the surface penetrant to make it water-washable. The excess penetrant is washed off using a low pressure (30 to 40 psi) spray of cold water, thoroughly dried, and the developer applied. The penetrant is drawn to the surface so that the flaw indications will become visible as a brilliant greenish-yellow color when exposed to black light.

The Types V and VI inspection processes are used (1) when inspecting large volumes of parts; (2) a higher sensitivity than group IV materials is required or desired; (3) the part is contaminated with acid or other chemicals that will harm water-washable penetrants; (4) discontinuities are wider than their depth; (5) variable, but controlled, sensitivities are necessary so that nondetrimental discontinuities can be disregarded while harmful or detrimental discontinuities are detected; (6) inspecting parts which may have defects that are contaminated with inservice soils; (7) inspecting for stress cracks, intergranular corrosion or grinding cracks; and (8) when high visibility is required.

TYPE VII, SOLVENT-REMOVABLE FLUORESCENT DYE PENETRANT.—The Type VII inspection process uses group VII materials which consist of a solvent-removable fluorescent penetrant, a penetrant remover (solvent), and a nonaqueous wet developer. The penetrant

is not water-washable but is removed instead with solvent penetrant remover.

After precleaning and drying, the penetrant is applied by one of the four methods and allowed to dwell on the surface of the item being inspected for a predetermined period of time. The penetrant is then removed from the surface with the solvent remover and the surface allowed to thoroughly dry. The developer is then applied, and the penetrant will bleed from the discontinuity into the developer so that the flaw indications will become visible when exposed to black light.

The Type VII inspection process is used when spot inspection is required and the water-rinsing method is not feasible because of part size, weight, surface condition, lack of water, or lack of heat for drying.

Interpreting Results

If the procedures are properly followed, the results of penetrant inspections are reliable. However, there are two conditions which may create accumulations of penetrant that sometimes are confused with true surface cracks.

The first condition is a result of poor washing. If all the surface penetrant is not removed in the washing or rinse operation following the penetration time, the unremoved penetrant will be visible. This condition is usually easy to identify since the penetrant will be in broad areas rather than in the sharp patterns found with true indications. When accumulations of unwashed penetrant are found on a part, the part should be completely reprocessed. Degreasing is recommended for the removal of all traces of the penetrant.

Another condition which may create false indications is where parts are press-fit to each other. For example, if a wheel is press-fit onto a shaft, the penetrant will show an indication at the fit line. This is perfectly normal since the two parts are not meant to be welded together. Indications of this type are easy to identify since they are so regular in form and shape.

The success and reliability of the penetration inspection depend upon the thoroughness with which the operator prepares the part from the precleaning all the way through to the actual search for indications. It is not a method by which a part is thrown into a machine which separates the good parts from the bad. The operator must carefully process the part, search out indications, and then decide the seriousness of defects found in order to determine the disposition of parts with indications. Penetrant inspections are important tools for finding defects before those defects grow into failures. It is up to the operator to get the most out of the method used.

Fluorescent indications, when viewed under black light, fluoresce brilliantly and the extent of the indication marks the extent of the defect. Pores, shrinkage, lack of bond, and leaks will show as glowing spots, while cracks, laps, or forging bursts will show as fluorescent lines. Where a large defect has trapped a quantity of penetrant, the indications will spread on the surface. Experience in the use of the method allows interpretation to be drawn from the extent of the spread as to the relative size of the defects. Grinding into certain defects, or sectioning and viewing under black light, will rapidly build up experience and knowledge of the character of defects lying below various types of indications.

For best results, inspection should be done in a darkened area. The darker the area of inspection, the more brilliant the indications will show. This is extremely important when looking for very fine indications. The inspection table should be kept free of random fluorescent materials. If penetrant has been spilled in the inspection area, on the table, or on the operator's hands, it will fluoresce brilliantly and may confuse the operator.

Visible dye penetrant indications appear as red lines. As the developer dries to a smooth white coating, red indications will appear at the locations of defects. If no red indications appear, there are no surface flaws present. No special lighting is required for the visible dye penetrant inspection.

It is possible to examine an indication of a discontinuity and to determine its cause as well as its extent. Such an appraisal can be made if something is known about the manufacturing processes to which the part has been subjected. The extent of the indication, or accumulation of penetrant, will show the extent of the discontinuity, and the brilliance will be a measure of depth. Deep cracks will hold more penetrant and therefore will be broader and more brilliant. Very fine openings can hold only small amounts of penetrant and therefore will appear as fine lines.

The most effective training tool for identifying and recognizing defects is a collection of

parts with typical defects which can be referred to frequently. Parts that have been rejected because of defects should be clearly marked or partially damaged so that they will not be confused with acceptable parts. Unless the defects are extremely large, the indications will remain on the parts for several months or longer.

MAGNETIC PARTICLE INSPECTION

Magnetic particle inspection is a method of detecting invisible cracks and other defects in iron and iron alloy material. This method of inspection is not applicable to nonmagnetic parts. Neither may parts be inspected in the installed condition.

The magnetic particle inspection process consists of magnetizing the part electrically and then applying tiny iron particles to the surface of the part. In an undamaged part the iron particles will arrange themselves in lines parallel to the lines of magnetic force (flux lines) on the surface of the part. If an imperfection exists on or near the surface of the part, the flux lines will be disturbed and opposite poles (positive and negative) will exist on each side of the imperfection. This is called a discontinuity. The discontinuity causes a new, smaller magnetic field to be set up about the imperfection which alters the regular pattern of the lines of force over the entire part. Some of the metallic particles arrange themselves in a pattern about the imperfection. This pattern, known as an "indication," assumes the approximate shape and size of the surface projection of the defect in the metal.

This type of inspection is performed mainly in industrial type activities inasmuch as bulky equipment (either fixed or mobile) is required. Other disadvantages of this method of metals inspections are as follows:

1. The part may have to be magnetized in more than one direction since imperfections lying along the direction of the flux lines may not show up.
2. The part must be demagnetized upon the completion of the inspection and between inspections.
3. Deep-lying imperfections may escape detection altogether.

RADIOGRAPHIC INSPECTION

Radiographic inspection procedures operate on the principle that doctors employ in X-raying the human body. X-rays are projected through the part being inspected and the result is captured on film, which is then developed much like a photographer processes film from his camera. This inspection medium, in a portable unit, provides a fast reliable means for checking integrity of components and structural members in the installed condition.

The primary purpose of portable X-ray is to locate defects or flaws in metal structures with little or no disassembly. This is in marked contrast to other types of nondestructive testing which usually require removal, disassembly, and stripping of paint from the suspected part before inspection can be accomplished.

Due to the nature of X-ray, extensive training is required to become a qualified radiographer, and only qualified radiographers are allowed to operate the X-ray units. The Navy conducts a radiography course at the Naval Air Technical Training Unit, Jacksonville, Florida, for certain aviation ratings, certain Marine Corps personnel, and eligible civil service personnel.

ULTRASONIC INSPECTION

This type of inspection utilizes a small portable machine which generates electrical impulses that are converted to acoustical energy at ultrasonic (above the audible range) frequencies. These sound vibrations are sent into the material under test. All boundary changes (including flaws) in or on the material reflect the vibrations back to their starting point in much the same manner as radar. The trace of the reflected sound waves is pictured on a cathode-ray tube (scope). Pips returned from the opposite side of the material will all be of uniform size and spacing if the material is of uniform thickness. Flaws or discontinuities in the material are indicated by shorter pips between the thickness pips. The "in-between" pips provide an accurate indication of the size, shape, and location within the material of flaws and imperfections.

EDDY CURRENT FLAW DETECTION

Inspection of metals with eddy current equipment is accomplished through a balanced bridge circuit contained within the equipment. A probe attached to the indicating unit and being a part of the balanced circuit is passed over a

crack or break. The eddy currents flowing around but not in the probe react on the probe and cause an imbalance on the formally balanced circuit. The amount of imbalance is indicated by needle deflection on a meter on the front of the indicating unit, therefore indicating the extent of the flaw.

CORROSION ELIMINATION

When corrosion of components or surfaces of support equipment has been discovered, the first step to be taken should be the safe and complete removal of the corrosion deposits or replacement of the affected part. Which of these actions to be taken depends upon the degree of corrosion, the extent of damage, the capability to repair or replace, and the availability of replacement parts. Any part which has been damaged by corrosion should be replaced if continued use is likely to result in failure.

Areas to be treated for corrosion deposit elimination must be clean, unpainted, and free of oil and grease. Chips, burrs, flakes of residue, and surface oxides must be removed. However, care must be taken to avoid removing, at the same time, too much of the uncorroded metal. Corrosion deposit removal must be complete. Failure to clean away surface debris permits the corrosion process to continue even after refinishing the affected areas.

When corrosion is present, any protective paint films must be removed to insure that the entire corroded area is visible. After the corrosion has been removed the extent of damage must be assessed. It is at this point that the determination is made to repair or replace the affected part or to perform a corrosion correction treatment. This treatment involves the neutralization of any residual corrosion materials that may remain in pits and crevices, and the restoration of permanent protective coatings and paint finishes.

PAINT REMOVAL

Paint removal operations may involve the stripping of small areas, whole panels, or the entire item of equipment, depending upon the condition of the existing surface finish and the extent of corrosion present. Small areas and panels to be stripped of paint are outlined by masking and then applying the stripper. The stripping of entire areas requires certain preliminary steps. These steps are discussed later in this section.

Materials

All paint removers are toxic and caustic to some extent; therefore, both personnel and material safety precautions must be observed in their use.

The following materials will do the stripping jobs commonly encountered with aviation support equipment, if they are used in accordance with prescribed instructions.

GENERAL PAINT AND ENAMEL REMOVER, SPECIFICATION TT-R-248.— This material is a good, nonflammable, water-rinsable, paint remover. It is intended for stripping lacquer and enamel coating systems from metal surfaces and can be applied by fluid spray or brush.

This material is water rinsable after application and can be applied several times on stubborn coatings. It should never be permitted to contact acrylic windows, plastic surfaces, or rubber products. This material has a 12- to 18-month shelf life. The chlorinated solvents contained in the stripper react with water to form hydrochloric acid on extended or improper storage. Store stripper indoors or in an area well protected against weather conditions.

This stripper is also toxic. Avoid prolonged breathing of fumes and skin contact. Wear goggle-type eyeglasses and protective clothing when using it.

PAINT REMOVER, SPECIFICATION MIL-R-81294.—This is a new epoxy paint remover for use in the field. This remover will strip acrylic and epoxy finishes very satisfactorily. Acrylic windows, plastic surfaces, and rubber products are adversely affected by this material. This material should not be stocked in large quantities as it ages rapidly, degrading the results of stripping action.

Procedures and Precautions

The stripping procedure provided in this section is a general method applicable to an entire item of support equipment. When small areas or entire panels are to be stripped, the procedure is modified accordingly.

Stripping should be accomplished outside in shady areas wherever possible. If stripping must be done in a hangar or other enclosure,

adequate ventilation must be assured. An electrical ground should be provided. Stripping operations produce static electrical charges, creating a fire hazard which a good ground connection will eliminate.

Using approved tapes and papers, mask off all openings that will allow the stripper to get into critical cavities. All seams and joints and components, such as brakes, must be masked off with a remover-proof barrier material. Fabric, acrylic, and rubber surfaces must be thoroughly protected.

Some paint removers may be used as received; others may require mixing. In any event, follow the recommended instructions received with the remover. Use about 2 gallons of remover in a 5-gallon container to avoid spillage. Always beginning on the upper surfaces, a generous amount of stripper should be sprayed on or daubed on with a bristle brush. The stripper should not be spread in a thin coat like paint, since it will not loosen paint sufficiently for removal, and the remover may dry on the surface of the metal, requiring a reapplication. The surface to be stripped should be covered completely with the stripper. Also during application, extreme care should be used when stripping gastight or watertight seams, as the remover tends to destroy the integrity of such seams upon contact. In such areas, the seams or openings must be masked and hand stripped later.

It may take from 10 minutes to several hours, depending on the temperature, humidity, and the condition of the paint, for the paint to soften. The softening process may be checked occasionally by scraping with a fiber scraper. If the remover begins to dry before the paint film has softened, reapply remover.

Loosened paint may be removed with fiber scrapers, bristle brushes, and rags. Steam or high-pressure water may be used to speed up the removal process; however, extreme care in their use is required. Rinse away paint and stripping compound, using detergent cleaning compound (see Soaps and Detergent Cleaners) and warm water. Water temperature should be from 110°F to 120°F.

After the paint and stripping compound have been removed, the surface must be wiped with rags wet with an approved solvent such as Stoddard Solvent. The next step is to remove all masking tape and carefully strip away the remaining paint it covered, using rags slightly dampened with an approved solvent cleaner such as Methyl-Ethyl-Ketone (MEK).

Mechanical Strippers

Abrasive paper, wire brushes, VAC-U-blasting, pneumatic sanders, and scrapers are all used for paint removal. They may be used for the entire job or for small areas remaining after the chemical stripping process. These mechanical materials and tools are also used for the removal of corrosion, which is discussed in the following section.

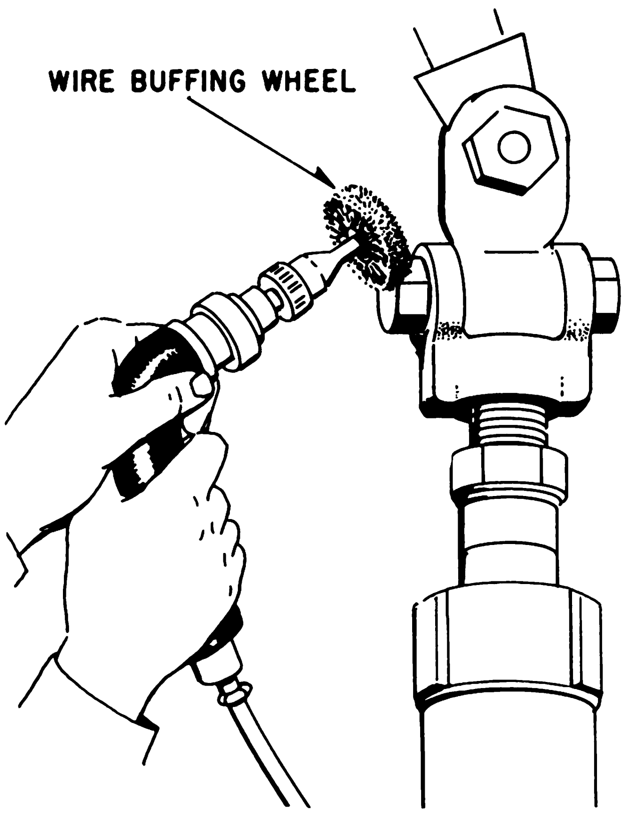
CORROSION REMOVAL

After the paint has been removed from corrosion-damaged areas of metal surfaces, it is necessary to remove all corrosion deposits before an accurate assessment of damage can be made. The different corrosion removal processes required by the various metals include chemical treatment to prevent or retard further corrosive attack. These chemical treatments are discussed as a part of the corrosion removal processes in this section. Further chemical treatments are applied for the purpose of improving paint adhesion if it is determined that the corrosion damage is tolerable and the affected parts may remain in service. Prepaint treatments are discussed in a subsequent section of this chapter.

Corrosion Removal From Iron and Steel

The most practical means of controlling the corrosion of steel is the complete removal of the corrosion products (rust) by mechanical means. Except on highly stressed steel surfaces, the use of abrasive papers, small power buffers (fig. 17-9) and buffing compounds, hand wire brushing, and steel wool are all acceptable cleanup procedures. It is a recognized fact, however, that in any such uses of abrasives, bits of iron rust will usually remain in the bottom of small pits and other surfaces. As a result, a part once rusty usually corrodes again, more easily than it did the first time.

The dry honer, discussed in greater detail in chapter 10, is used to a great extent for the removal of corrosion. This machine is effective for the removal of corrosion from small areas especially around seams, rivet heads, and bolt heads. In addition, the vacuum effect of



AM.58
Figure 17-9.—Corrosion removal from steel.

the dry honer removes practically all of the abrasives and corrosion contaminated particles from the surface. The surface of the workpiece must be free of dirt, grease, and oil.

HIGHLY STRESSED STEEL SURFACES.—Any corrosion on the surface of highly stressed steel, such as that used on cranes, weapons loaders, etc., is potentially dangerous, and careful removal of the corrosion deposits is mandatory. Surface scratches or changes in the surface molecular structure due to overheating can cause sudden failure. Removal of corrosion products must be accomplished by careful processing, using mild abrasive papers such as rouge or fine grit aluminum oxide, or fine buffing compounds on cloth buffing wheels. It is essential that the steel surface not be overheated while buffing. After this careful removal of surface corrosion, protective paint finishes should be reapplied immediately.

STAINLESS STEEL ALLOY SURFACES.—When processing corroded stainless steel surfaces, certain precautions must be considered.

1. Stainless steel surfaces are never wire brushed under any condition.
2. If removal of heat scale is necessary, the part should be removed and sent to the nearest overhaul and repair activity for the proper chemical treatment.

CADMIUM PLATED SURFACES.—As stated previously, cadmium platings are still offering protection even when they show discoloration ranging from white to brown to black on their surfaces. This discoloration should never be removed for appearance sake alone. Not until the characteristic color peculiar to corrosion of the base metal appears should steps be taken.

Corrosion present should be removed by rubbing lightly with stainless steel wool. Under no circumstances should a wire brush, stainless or otherwise, be used on cadmium plated surfaces as these will remove more plating than corrosion. After the corrosion has been removed, the affected area should be swabbed with a chromic acid solution and, after 30 to 60 seconds, rinsed with clean water and dried with clean cloths or low-pressure compressed air. The part is then ready for a protective paint coating.

Corrosion Removal From Aluminum

There are three types of aluminum surfaces insofar as corrosion removal is concerned. They are clad, anodized, and exfoliated.

CLAD ALUMINUM SURFACES.—Pure aluminum has considerable corrosion resistance compared to aluminum alloys, but has little or no structural strength. It has been learned that an extremely thin sheet of pure aluminum laminated on to each side of an aluminum alloy sheet improves the corrosion resistance with little impairment of strength. The trade name of this aluminum laminate as originated by the Aluminum Company of America is "Alclad." From this trade name has derived the terms "clad" and "cladding." Not all sheet aluminum is clad, especially those alloy sheets from which small brackets, gussets, fittings, etc., are made. The pure aluminum is very soft and the fabrication processes would severely damage or destroy the clad surfaces.

To remove corrosion from clad surfaces the corroded areas should be hand polished with household abrasives such as Bon Ami or Ajax, or with a specification metal polish, MIL-P-6888. This polish effectively removes stains and produces a high-gloss, lasting polish on unpainted clad surfaces. If a surface is particularly difficult to clean, Compound, Cleaner and Brightener, Type II (specification MIL-C-5410) may be used. Mixed 50-50 percent with water, this compound used before polishing will shorten the time and lessen the effort necessary to get a clean surface. During both the foregoing polishing and brightening operations, care must be taken to avoid unnecessary mechanical removal of the protective clad layer and the exposure of more susceptible, but stronger, aluminum alloy base.

If there is any surface corrosion present it should be treated by wiping down with an inhibitive material such as the Chemical Surface Films for Aluminum Alloys, available under specification MIL-C-5541. Allow the solution to remain on the corroded area for about 5 minutes when working in the shade, and less than 5 minutes in sunlight. Remove the excess by wiping the surface with dry clean cloths. If the alclad material is to be used in the unpainted condition, it may now be overcoated with an approved waterproof, solvent type wax. If the treated alclad surface is to be painted, no wax is used, and the paint pretreatment is applied instead.

ANODIZED ALUMINUM SURFACES.—Anodizing is the most common surface treatment of nonclad aluminum alloy surfaces. The aluminum alloy sheet or casting is the positive pole in an electrolytic bath in which chromic acid or other oxidizing agent produces an aluminum oxide film on the metal surface. Aluminum oxide is naturally protective, and anodizing merely increases the thickness and density of the natural oxide film. When this coating is damaged in service, it can only be partially restored by chemical surface treatments. Therefore, any processing of anodized surfaces, including corrosion removal, should avoid unnecessary destruction of the oxide film.

Aluminum wool, nylon webbing impregnated with aluminum oxide abrasive, or fiber bristle brushes are the approved tools for cleaning anodized surfaces. The use of steel wool, steel wire brushes, or harsh abrasive materials on any aluminum surfaces is prohibited. Producing a buffed or wire brush finish by any means is also prohibited. Otherwise, anodized surfaces are treated in much the same manner as other aluminum finishes.

EXFOLIATED SURFACES.—As previously described, exfoliation is a separation along the grain boundaries of metal and is caused by intergranular corrosion. On items such as tow bars, the mechanical removal of all corrosion products and visible delaminated metal layers must be accomplished in order to determine the extent of destruction and to evaluate the remaining structural strength of the component. Metal scrapers, rotary files, and other necessary tools are used to assure that all corrosion products are removed and that only structurally sound aluminum remains. Inspection with a 5- to 10-power magnifying glass, or the use of dye penetrant will aid in determining if all unsound metal and corrosion products have been removed. When complete removal has been attained, any rough edges should be blended or smoothed out even though this involves the removal of more metal. Grinding, where required, can best be accomplished by using rubber base wheels into which tiny particles of aluminum oxide abrasives have been impregnated.

Chemical treatment of exposed surfaces is applied in the same manner as any other aluminum surface.

Corrosion Removal From Magnesium

Magnesium corrosion reprotection involves the maximum removal of corrosion products, the partial restoration of surface coatings by chemical treatment, and a reapplication of protective coatings.

After cleaning the surface and stripping paint, if any, as much of the corrosion products as possible should be broken loose and removed using a stiff bristle brush. Steel wire brushes, carborundum abrasives, or steel cutting tools should not be used.

The corroded area is treated liberally with a solution of chromic acid and battery electrolyte. The solution is worked into pits and crevices by brushing the area while still wet, again using a bristle rather than a metal brush. After the chromic acid solution has remained in place from 5 to 30 seconds, the excess should be wiped up with a damp cloth. If any excess solution is allowed to dry on any painted surfaces the paint film will be ruined. As soon

as the surfaces are dry after the damp cloth wiping, the original protective paint scheme should be restored.

NOTE: Corrosion removal and treatment, as well as painting, is usually documented on a Support Action Form (SAF). The appropriate information is documented in a manner similar to that shown in the SAF for cleaning an item of support equipment. (See fig. 17-6.) In this case the support code 040 would be used rather than 020, which is used for cleaning. At times it may be necessary, or required, to document corrosion control work on a MAF (i.e., extensive corrosion work in certain areas of an item of support equipment, when entries in historical records must be made, etc.).

PAINTS AND THEIR APPLICATION

The exterior surfaces of most items of ground support equipment are painted. The primary purpose of the paint is to provide adequate protection against rust or corrosion. In addition, the color of the paint provides a visible means of identifying the purpose of the equipment and designating the use of the vehicle in certain areas. For example, all vehicles and equipment used primarily for service, maintenance, etc., on aircraft landing, parking, and maintenance areas are marked in a distinctive manner for a high degree of visibility. For this reason this equipment is painted yellow and, in addition, black and yellow warning stripes are applied to the rear of these items of equipment.

When new equipment is received, it is of course, painted the appropriate color. However, through usage and the inspection and removal of corrosion, the equipment requires repainting from time to time. In some instances the entire surface of an item of equipment requires repainting. More often, touchup painting of small areas is required.

Although there are several types of paint—such as epoxy, lacquer, enamel, etc.—enamel is the most common type used on ground support equipment. Therefore, the application of enamel and the required primer is discussed in the following paragraphs.

PRIMING

The first step of the painting procedure is to apply a base coat (primer) to the bare metal surface. The main purpose of the primer is to improve paint adhesion. The most common primer used on support equipment is zinc chromate (specification MIL-P-8585). This primer is bright yellow in color.

Zinc chromate may be applied by brushing or spraying. It may be thinned to the desired consistency with toulene or mineral spirits. Only a light coat of primer should be applied to the surface. The primer dries adequately for over-coating within 1 hour.

PAINTING

As previously stated, yellow enamel is the most common top coat used on ground support equipment. Black enamel is used for identification markings. Unless otherwise specified, these colors must meet certain Federal Standards. The standards are identified by color numbers.

The enamel is usually applied by spraying; however, small areas may be touched up by brushing. The desired consistency may be obtained by thinning the enamel with toulene. The toulene will also speed the drying process. The paint should be mixed according to the directions on the container.

Two coats of paint are required over the primed surface. A thin mixture should be used for the first coat. This facilitates quick drying and provides a tacky surface for the application of the finish coat. The mixture for the finish coat should be that prescribed by the paint manufacturer. The mixture must be adequate to produce a smooth even surface. The surface must be free of runs, sags, and overspray. Spraying techniques are covered later in this chapter.

Many of the painting jobs required of the ASH are those of touching up small areas. Through normal usage of the equipment, painted surfaces become cracked and chipped. Often small areas must be stripped for the removal of corrosion deposits. These small areas must be repainted as soon as possible.

Much of the effectiveness of any paint surface and its adherence depends on the careful preparation of the damaged surface prior to touchup. All loosened paint should be brushed off, and curled or flaky edges must be removed if good adhesion is to be realized. The touchup paint should overlap onto the existing painted surfaces. The touchup materials will not adhere properly to glossy finishes. Also any

edges of the existing film will show through the overlap unless they are smoothed out.

To break the gloss of existing finishes and to feather (smooth out) the edges for overlap, sand with fine sandpaper. Care must be taken to avoid cutting through the existing surface treatments. The sanded pattern should provide no more than one-half inch of overlap for the new paint.

Following sanding, a water rinse is used to remove the abrasive residues. Next, all sanded areas and exposed bare metal surfaces are wiped down with mineral spirits, followed with a detergent wash. When dry, the surface is primed and painted following the procedures previously described.

When painting a complete item of equipment, it is not always necessary to remove all the old paint. Old paint in good condition is an excellent base for repainting. Light sanding will break the gloss of the old paint. All chipped and damaged areas must be prepared as previously described. The primer and the first coat of paint are then applied to the damaged areas. Then the finish coat is applied to the entire surface.

IDENTIFICATION MARKINGS

In addition to color identification, some items of ground support equipment are further identified by standard identification markings. The standard marking for USN numbered mobile equipment, such as tow tractors, contains three lines of letters and numbers. The first line is the agency identification—U.S. NAVY. The second line is the identification number of the vehicle. For Navy registered vehicles, such as towing tractors, this is the registration number. It is a seven-digit number, for example, 49-96758. The first two digits indicate the classification of the vehicle. In the example, 49 indicates the vehicle as a Tractor, Aircraft Towing. The last five digits are the identification number for the vehicle. The last line of the standard marking is the legend—FOR OFFICIAL USE ONLY.

Due to space limitations, this identification marking may be modified to one line. In this situation the previous example appears as: USN 49-96758.

The location of the identification marking depends on the type of the equipment. It is normally required on both sides and the rear and must be clearly visible.

The size of the letters and numbers also varies with the type of equipment. The agency identification and the identification number are generally 1 1/2- to 3-inch letters and numbers, depending on the size of the equipment. The legend varies in size from 3/4 to 1 inch. The modified markings are generally 1 1/2 to 3 inches in size.

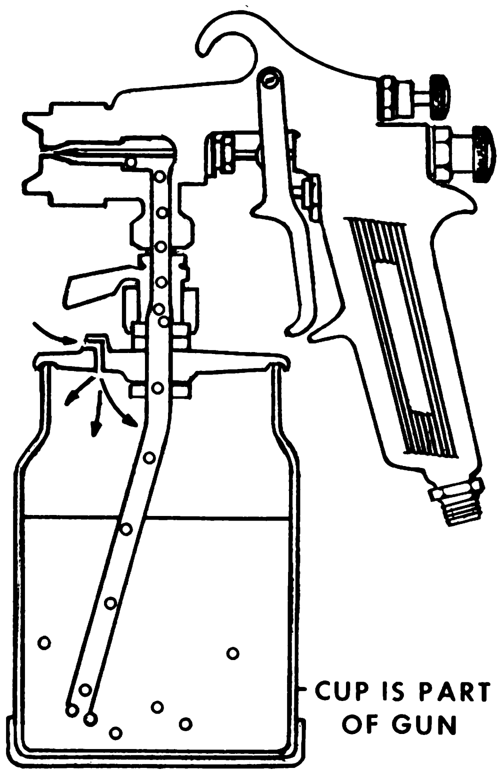
In addition to standard identification markings, many items of equipment require special markings. Special markings include safety markings, such as NO SMOKING and FLAMMABLE, and service markings, such as tire inflation pressure, grade of gasoline, etc. Safety markings are located in clearly visible areas on the sides and rear of the equipment. Service markings are placed on shields, panels, or frames immediately adjacent to the service location. The size of the safety markings varies with the size of the equipment and ranges between 1 1/2 to 3 inches. Service markings are generally one-half inch in size.

In addition to the standard and special markings, black and yellow warning stripes must be applied to the rear of self-propelled equipment. The alternating stripes are 4 inches wide and are placed at an incline of 45 degrees from the left and right of the vertical center.

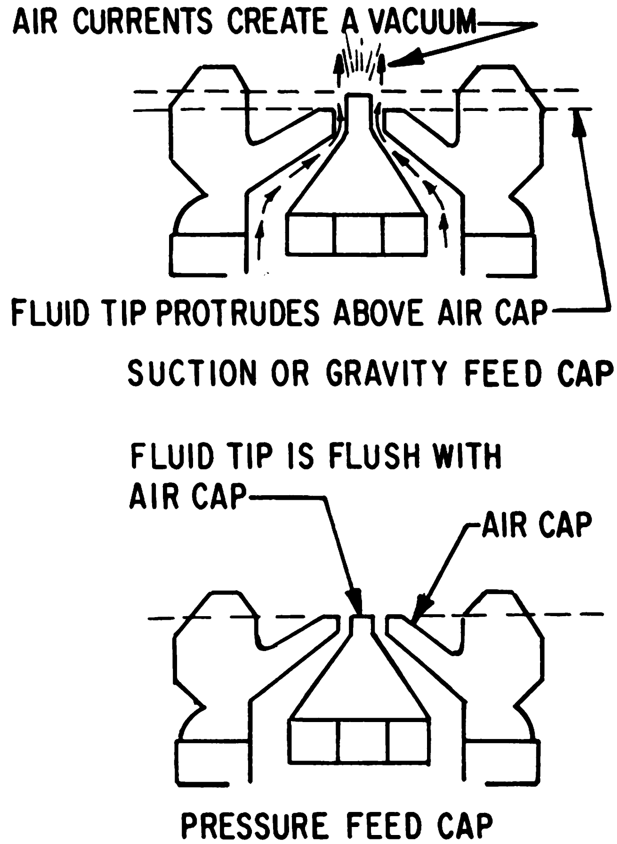
Application Methods

There are two common methods of applying identification markings to the equipment—the stencil and paint method and the decal method. The stencil and paint method requires the use of gummed-back (pressure sensitive) paper stencils and then painting over the stencil. After the application of the stencil and before painting, the webs must be removed from the letters and numerals of the stencil. This will allow the letters and the numbers to appear on the surface without broken lines. These stencils are available from commercial sources in individual letters and numbers of assorted sizes and also complete words.

Decals are available in two types—nonreflective and reflective. The reflective type is authorized for vehicles and equipment used on airfield landing areas. The decals are available from commercial sources and can be purchased with die-cut and prespaced letters and numbers in sizes and colors that conform to Navy requirements.



AM.419
Figure 17-10.—Suction-feed type spray gun.



AM.420
Figure 17-11.—Suction and pressure fluid tips and air caps.

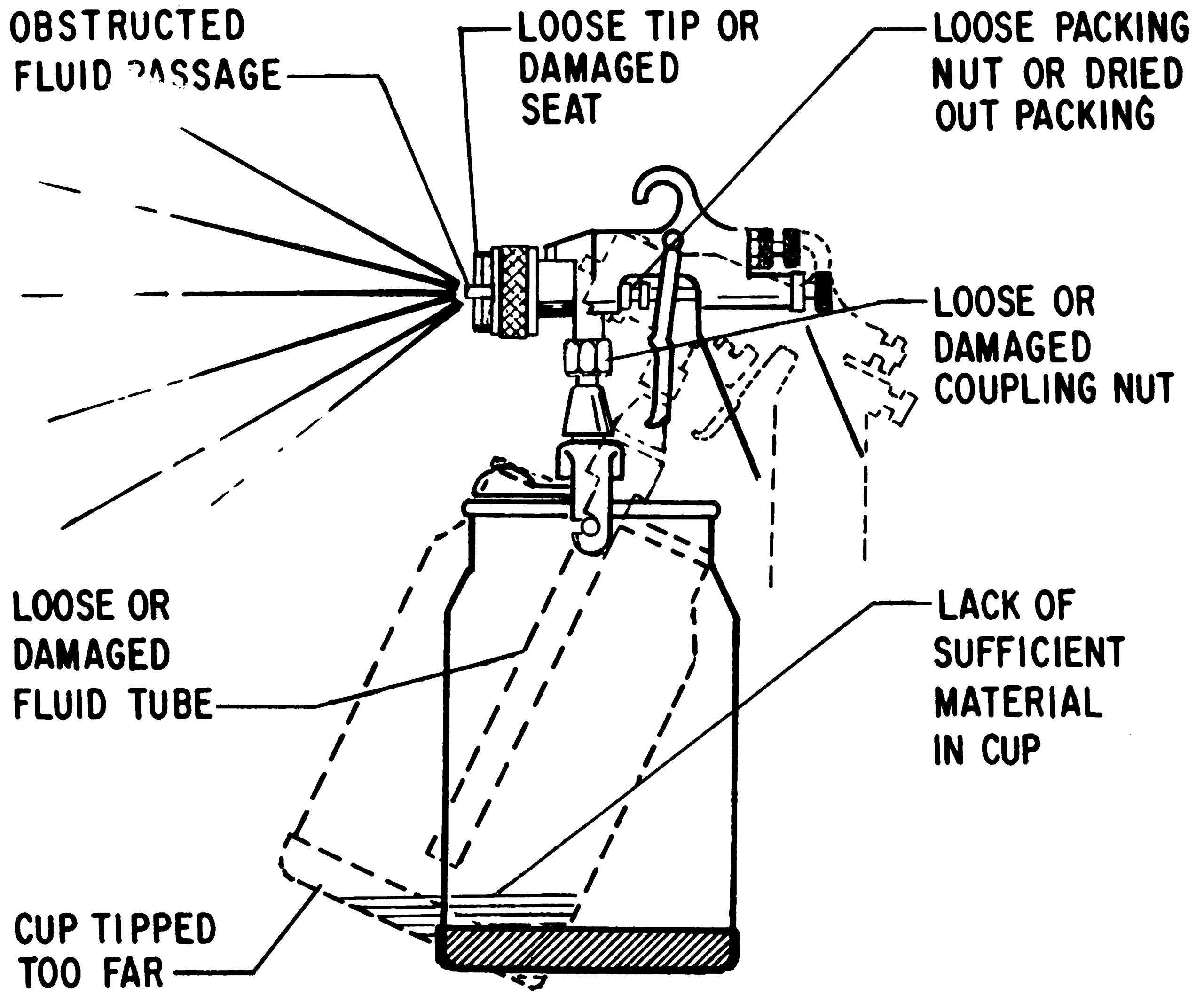
REFLECTIVE MARKINGS

Support Equipment Change 1879 specifies that ground support equipment and other vehicles or equipment which are used or operated on or around flight line areas shall be marked with retro-reflective materials. These materials consist of reflective, pressure sensitive, 2-inch tape, Specification L-S-300, and reflective, yellow paint, Specification TT-C-001060. When properly applied, these materials provide improved visibility of flight line support equipment during night aircraft taxiing operations.

The tape is used in most applications. It should be applied along the extreme perimeter of the equipment so that it will reflect the general outline configuration of the equipment when operating under reduced lighting conditions. When possible, the tape should be applied to the entire perimeter of the equipment. However, equipments which have perimeter surfaces containing compound curves at the corners or large rivets, nuts, bolts etc., need not be marked in these particular areas provided the other markings provide a general outline of the equipment.

Wheel chocks, tiedowns, and other small equipment whose configuration does not readily lend itself to the application of reflective tape shall be marked with 2-inch circular stripes of reflective paint. For example, wheel chocks shall be marked around the middle and each exposed end.

Prior to applying the tape or paint, the surface must be free of all loose scale and dirt. In addition, all deposits of cleaning compounds



AM.421

Figure 17-12.—Causes of jerky or fluttering spray.

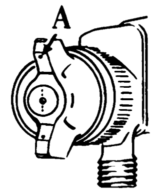
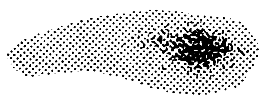
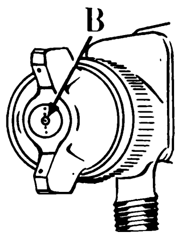
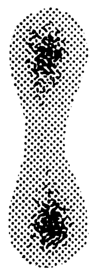
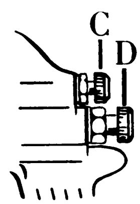
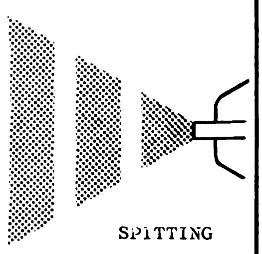
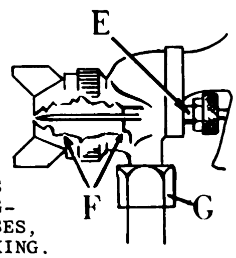
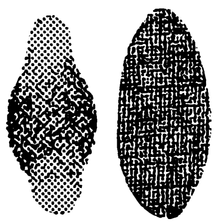
must be removed and the surface must be thoroughly dried.

The materials should be applied in accordance with the manufacturer's instructions. They should not be applied at temperatures below 50°F. When applying tape, any air bubbles that appear between the tape and the surface must be removed. This can be accomplished by gently forcing the bubbles to the edge of the tape with a small piece of stiff cardboard.

After applying tape, a sealing compound conforming to Specification TT-V-109 should be applied to the edges. This forms a fillet between the edge of the tape and the surface and, therefore, protects the edge of the tape.

Reflective material must not be haphazardly applied and must be free from ragged edges, voids, cracks, scales, air bubbles, blisters, or dirt.

Repair of damaged reflectorized areas can be made without stripping the original materials. Clean the damaged surface and apply new tape or paint as applicable over the affected area.

PATTERN	CAUSE	CORRECTION
	DRIED MATERIAL IN SIDE-PORT "A" RESTRICTS PASSAGE OF AIR THROUGH IT. RESULT: FULL PRESSURE OF AIR FROM CLEAN SIDE-PORT FORCES FAN PATTERN IN DIRECTION OF CLOGGED SIDE. 	DISSOLVE MATERIAL IN SIDE-PORT WITH THINNER. DO NOT POKE IN ANY OF THE OPENINGS WITH METAL INSTRUMENTS.
	DRIED MATERIAL AROUND THE OUTSIDE OF THE FLUID NOZZLE TIP AT POSITION "B" RESTRICTS THE PASSAGE OF ATOMIZING AIR AT ONE POINT THROUGH THE CENTER OPENING OF AIR NOZZLE AND RESULTS IN PATTERN SHOWN. THIS PATTERN CAN ALSO BE CAUSED BY LOOSE AIR NOZZLE. 	IF DRIED MATERIAL IS CAUSING THE TROUBLE, REMOVE AIR NOZZLE AND WIPE OFF FLUID TIP, USING RAG WET WITH THINNER. TIGHTEN AIR NOZZLE.
	A SPLIT SPRAY OR ONE THAT IS HEAVY ON EACH END OF A FAN PATTERN AND WEAK IN THE MIDDLE IS USUALLY CAUSED BY (1) TOO HIGH AN ATOMIZING AIR PRESSURE, OR (2) BY ATTEMPTING TO GET TOO WIDE A SPRAY WITH THIN MATERIAL.	REDUCING AIR PRESSURE WILL CORRECT CAUSE (1). TO CORRECT CAUSE (2), OPEN MATERIAL CONTROL "D" TO FULL POSITION BY TURNING TO LEFT. AT THE SAME TIME TURN SPRAY WIDTH ADJUSTMENT "C" TO RIGHT. THIS WILL REDUCE WIDTH OF SPRAY BUT WILL CORRECT SPLIT SPRAY PATTERN. 
 SPITTING	(1) DRIED OUT PACKING AROUND MATERIAL NEEDLE VALVE PERMITS AIR TO GET INTO FLUID PASSAGEWAY. THIS RESULTS IN SPITTING. (2) DIRT BETWEEN FLUID NOZZLE SEAT AND BODY OF A LOOSELY INSTALLED FLUID NOZZLE WILL MAKE A GUN SPIT. (3) A LOOSE OR DEFECTIVE SWIVEL NUT ON SIPHON CUP OR MATERIAL HOSE CAN CAUSE SPITTING.	TO CORRECT CAUSE (1) BACK UP KNURLED NUT (E), PLACE TWO DROPS OF MACHINE OIL ON PACKING, REPLACE NUT AND TIGHTEN WITH FINGERS ONLY. IN AGGRAVATED CASES, REPLACE PACKING.  TO CORRECT CAUSE (2), REMOVE FLUID NOZZLE (F), CLEAN BACK OF NOZZLE AND NOZZLE SEAT IN GUN BODY USING RAG WET WITH THINNER, REPLACE NOZZLE AND DRAW UP TIGHTLY AGAINST BODY. TO CORRECT CAUSE (3) TIGHTEN OR REPLACE SWIVEL NUT (G).
	A FAN SPRAY PATTERN THAT IS HEAVY IN THE MIDDLE, OR A PATTERN THAT HAS AN UNATOMIZED "SALT-AND-PEPPER" EFFECT INDICATES THAT THE ATOMIZING AIR PRESSURE IS NOT SUFFICIENTLY HIGH.	INCREASE PRESSURE FROM YOUR AIR SUPPLY. CORRECT AIR PRESSURES ARE DISCUSSED ELSEWHERE IN THIS CHAPTER.

AM.422

Figure 17-13.—Faulty spray patterns and how to correct them.

PAINTING EQUIPMENT AND TECHNIQUES

The ASH is called upon many times to use his skill and knowledge in the painting of ground support equipment. This type of work is normally performed during preventive maintenance inspections or when the painted surfaces of the equipment warrant touching up or repainting.

Since the types of paints were discussed earlier in the chapter, only the equipment and techniques in painting are covered in this section.

There are two general types of paint spray systems. Air pressure is required for the operation of both systems. In one system the air mixes with the paint as it forces the paint through the paint gun. In this training manual, this system is referred to as the air-mix system. In the other system, the air pressure provides the power to a pump which, in turn, pumps the paint from the container through the spray gun. The pressurized air does not come in contact with the paint. This system is known as the airless paint spray unit.

AIR-MIX SYSTEM

The air-mix system has been utilized for painting for many years. It is still the most widely used system in aviation maintenance activities. The major components of this system are described in the following paragraphs.

Spray Guns

The spray gun atomizes the material sprayed and the operator directs and controls the spray pattern through manipulation and minor adjustments of the spray gun. Spray guns are usually classed as either suction-feed or pressure-feed type. Each type can be further classified according to the type of container used to hold the paint material, and by the method in which the paint is drawn through the air cap assembly.

SUCTION-FEED TYPE.—The suction-feed spray gun is designed for small jobs. The container for the paint is connected to the spray gun by a quick-disconnect fitting, as illustrated in figure 17-10. The capacity of this container is approximately 1 quart.

The fluid tip of the suction-feed spray gun protrudes through the air cap as illustrated in figure 17-11. The air pressure rushing by the fluid tip causes a low-pressure area in front of the tip. This causes paint to be drawn up through the fluid tip where it is atomized outside the cap by the air pressure.

PRESSURE-FEED TYPE.—The pressure-feed type spray gun is designed for use on larger jobs where a large amount of spray material is to be used. With this type, the spray material is supplied to the gun through a hose from a pressurized tank. This spray gun is designed to operate on a high volume and low air pressure. This type of spray equipment reduces evaporation of the volatile substances of the mixture before striking the surface since the paint and air are mixed internally; in other words, a wetter coating is applied.

SPRAY GUN MAINTENANCE.—The maintenance of spray guns includes cleaning, lubrication, and repair. Some of the most common troubles encountered with spray guns are fluid and air leakage, jerky or fluttering spray, and faulty spray patterns.

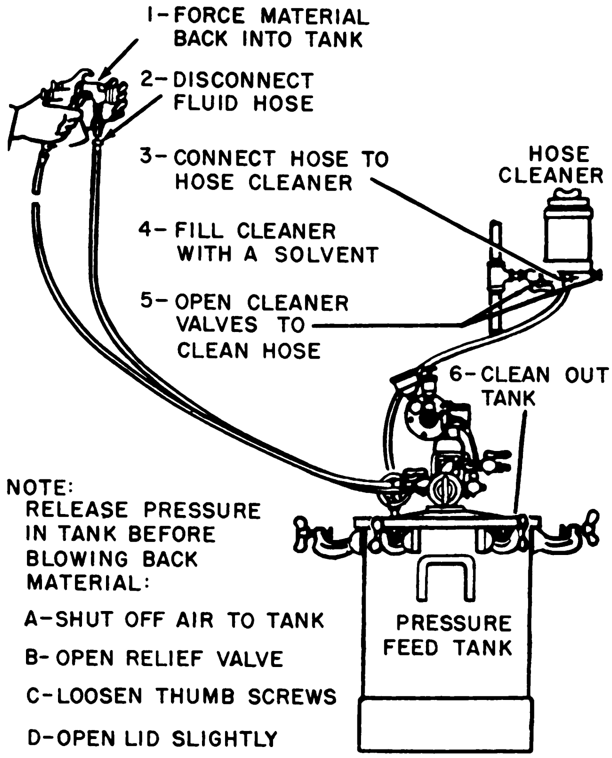
Fluid leakage at the front of the gun is an indication that the fluid needle is not seating properly. This may be caused by a fleck of dried material in the nozzle, or the fluid needle packing may be too tight. It may also be caused by a bent fluid needle, a broken fluid needle spring, or the wrong size fluid needle for the fluid tip.

Air leakage is a result of improper setting of the air valve. This may be caused by a bent stem, a broken spring, or a damaged valve or valve seat.

Jerky or fluttering spray is caused by obstructed fluid passage, loose tip or damaged seat, and air in the fluid line. The air can be inducted from several points on the equipment, loose packing nut or dried out packing, loose or damaged coupling nut, loose or damaged fluid tube, lack of sufficient material, and cup tipped too far. (See fig. 17-12.)

Faulty spray patterns, their causes, and how to correct them are shown in figure 17-13.

Spray guns should be cleaned immediately after each use. To clean the suction type gun, empty the container and pour in a small quantity of thinner or suitable solvent. Draw the solution through the gun by inserting the tube into the container. Move the trigger constantly to thoroughly flush passageways and the tip of the fluid needle. Remove the air cap and soak it in solvent. If this does not clear the holes in the air cap, remove the paint material, using a toothpick or broomstraw. Do not use

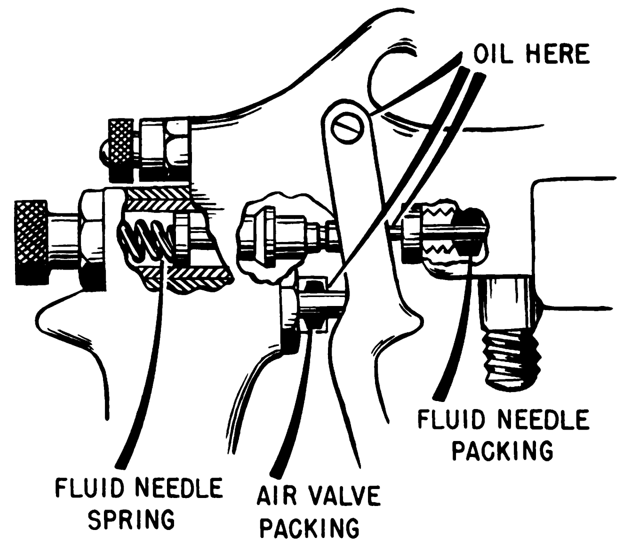


AM.423
Figure 17-14.—Cleaning pressure-feed spray gun.

wire or other metal objects which may cause permanent damage to the air cap.

To clean a pressure-feed gun, proceed as follows: Back off the fluid needle adjusting screw. Release the pressure from the pressure tank by means of the relief or safety valve. Hold a cloth over the air cap and operate the gun trigger. This forces the spray material back into the pressure tank. (See fig. 17-14.) Remove the fluid hose from the gun and the pressure tank. Attach a hose cleaner to the hose and run thinner or suitable solvent through the hose. Place the air cap in the cleaning fluid as stated above for the suction type gun.

NOTE: Do not immerse an entire spray gun in cleaning materials such as cleaning solvents and thinners. These materials dissolve the oil from the leather packings and cause the gun to have an unsteady spray.



AM.424
Figure 17-15.—Spray gun lubrication points.

The following parts of a spray gun require frequent lubrication: Fluid needle packing, air valve stem, and trigger bearing screw. Remove the fluid needle packing before using the gun and soften it with oil. The fluid needle spring should be coated with a specified grease. (See fig. 17-15.)

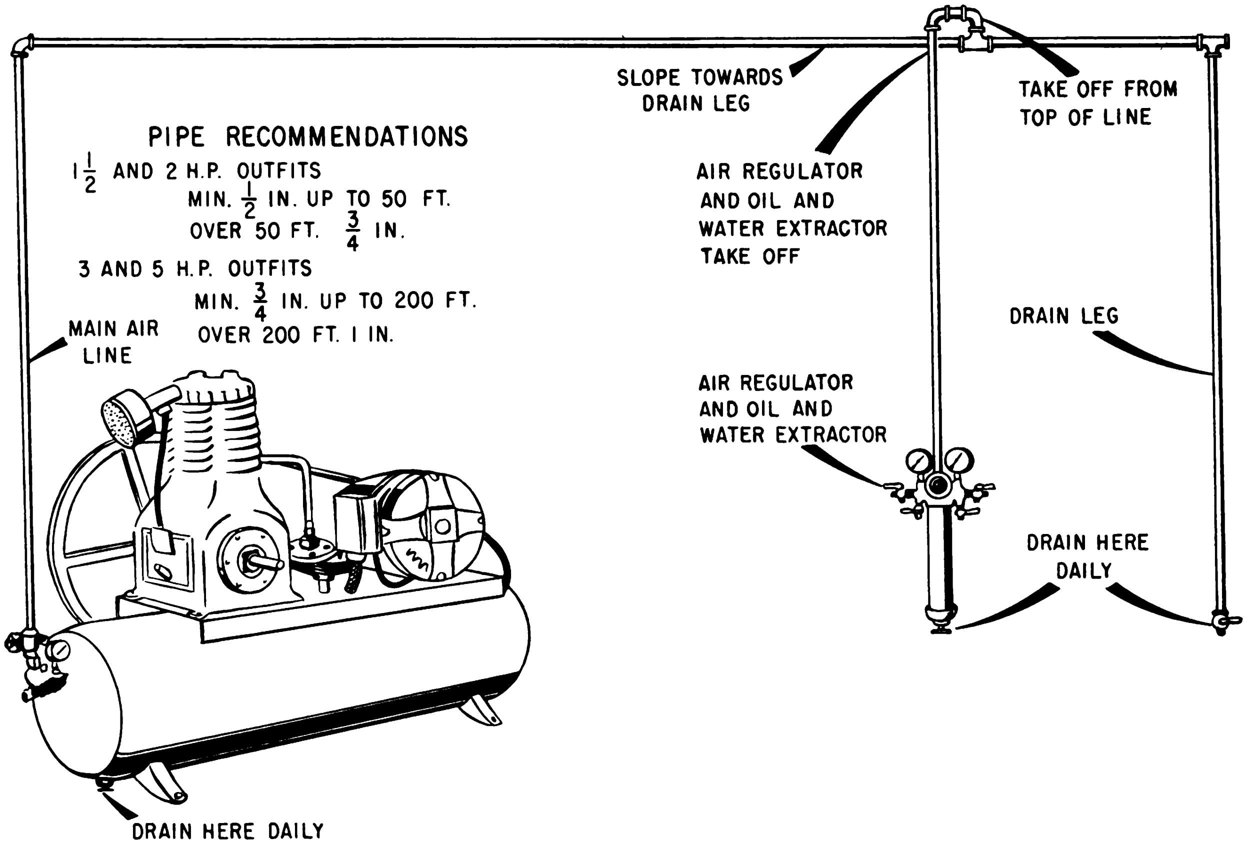
Air Compressors

In order to use spray guns, a source of compressed air is necessary. Either the portable or stationary air compressor unit may be used for this purpose. The types, operation, and maintenance of air compressors are discussed in chapter 13.

Air Regulators

The air regulator (or transformer) is used to regulate the amount of air pressure to the spray gun and to clean the air. The air delivered to the regulator always contains some oil from the compressor and some water caused by condensation, and many particles of dirt and foreign matter.

Air regulators are equipped with a pressure valve and pressure regulating screw. This



AM.427

Figure 17-16.—Compressor and air regulator installation.

makes it possible to regulate exactly the pressure delivered to the spray gun and prevents any pressure fluctuations. The air must pass through a sack or cleaner before it leaves the regulator. This cleaner is contained in the long cylindrical part of the regulator.

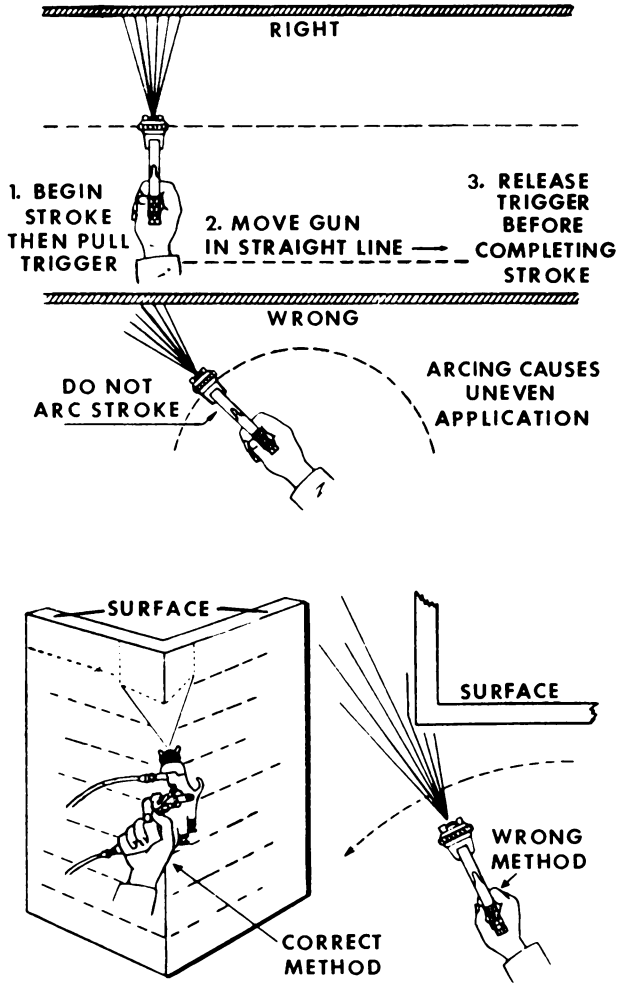
Air regulators are equipped with two gages. One gage shows the pressure on the main line while the other shows the pressure to the spray gun. A complete compressor and air regulator installation is shown in figure 17-16.

Spray Gun Technique

Proper spray gun technique is acquired and developed through knowledge of the equipment and experience of the operator. The spray gun should be held so the spray is perpendicular to the area to which the finish is being applied. Great care should be taken to insure that the prescribed distance from the gun to the work is maintained. This distance varies with the type of paint being used.

The gun should be held from 6 to 8 inches from the work for spraying enamels, depending on the width of the spray pattern. By comparison, this distance should be from 8 to 10 inches for spraying lacquers. Generally, with a narrow pattern, the gun is held the farther distances from the work (8 inches for enamels).

In general, a distance of less than 6 inches is undesirable, since the paint will not atomize properly, and "orangepeel" will result. A distance of more than 10 inches is equally undesirable, since particles of paint will strike the surface and cause "dusting" of the finish.



AM.428

Figure 17-17.—Correct and incorrect methods of spraying.

Examples of correct and incorrect spray gun techniques are shown in figure 17-17.

The distance the spray gun is held from the work is very important; however, there are other factors which must be considered and mastered. The manner in which the gun is held and operated is illustrated in figure 17-17. Move the arm and body with the gun to keep the spray perpendicular to the surface. Avoid pivoting or any circular movements of the wrist or forearm which will bring the gun closer to the surface when directly in front of the body.

It is important to "trigger" the gun in order to avoid an uneven coat building up at the beginning and end of the stroke. Triggering is the technique of starting the gun moving toward the area to be sprayed before the trigger is pulled, and continuing the motion of the gun after the trigger has been released.

Care must be taken to avoid too much overlapping on each pass of the gun or an uneven coat will result. The rate of stroke should be such as to produce a full, wet, even coat.

Once the job is started it must be carried through to completion without stopping.

The spray gun must be adjusted to obtain the desired spray pattern and flow of material. Figure 17-18 illustrates the principal parts of a typical spray gun, including the various adjustment points. The spreader adjustment dial is used in adjusting the width of the spray pattern. By turning the dial to the right, a round pattern is obtained; turning to the left gives a fan-shaped pattern.

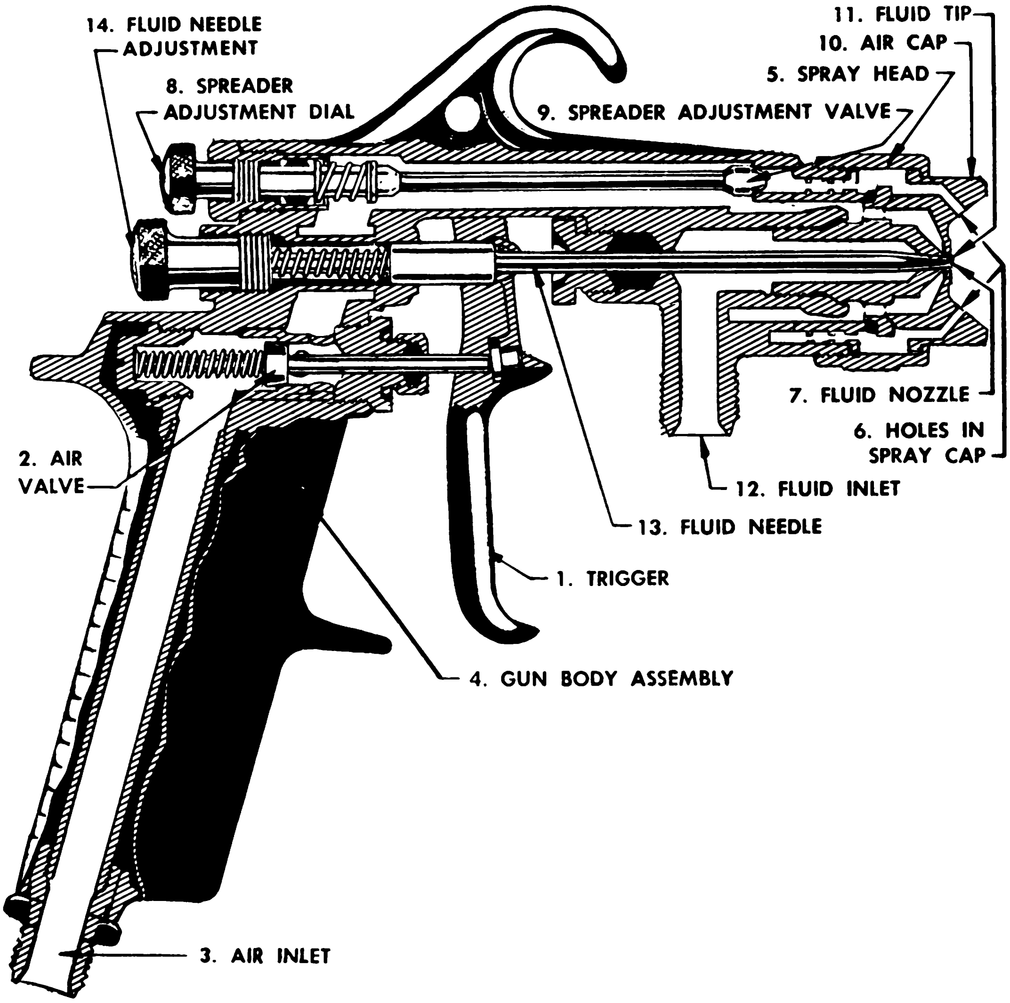
As the width of the spray is increased, more material must be allowed to pass through the gun to get the same coverage on the increased area. To apply more material to the area, the operator should turn the fluid needle adjustment (fig. 17-18) to the left. If too much material is applied to the surface, turn the fluid needle adjustment to the right.

In normal operation of the spray gun, the wings on the air cap are adjusted to the horizontal position, as illustrated in figure 17-19. This provides a vertical fan-shaped pattern, giving maximum coverage as the gun is moved back and forth parallel to the surface being painted.

The correct air and fluid pressure are important in all spray painting applications. These pressures vary with different types of paint materials; however, the ASH is primarily concerned with enamel materials. There are several pitfalls of incorrect pressures, some of which are listed as follows:

1. Too high an air pressure alone causes dusting of finish and rippling.
2. Too low an air pressure, coupled with too high fluid pressure, causes orangepeel.
3. Too high fluid pressure alone causes orangepeel and sags.
4. Too low fluid pressure alone causes dusting.

When using 20-foot air and fluid pressure hoses, maintain a pressure of approximately 50 psi for enamel. The pressure is measured



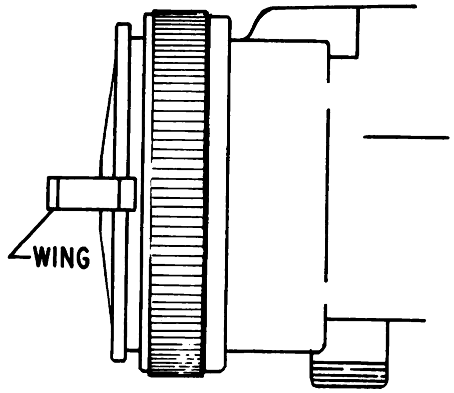
AM.429

Figure 17-18.—Sectional view of typical spray gun.

at the gun. Sufficient pressure must be maintained at the main line pressure regulator to obtain the above pressure and to compensate for the pressure drops encountered if additional lengths of hose are employed. The pressure at the gun should be rechecked if the main line pressure is changed for any reason. Fluid tank pressure for enamel should be 11 to 15 psi. A proportional increase should be allowed for additional lengths of hose up to 50 feet maximum. One pound fluid pressure may be added for each foot of height of the gun from the fluid tank level. Make frequent checks of air pressure at the gun with a test gage.

AIRLESS PAINT SPRAY SYSTEM

The airless system is a relatively recent development for spray painting. In this system, the paint is pumped from the container through a hose and out the spray gun. The air pressure required for this system supplies the power for an air motor which, in turn, provides the power for the pump. Hydraulic principles



AM.430

Figure 17-19.—Spray gun nozzle.

are involved in this action. In fact, the pump is sometimes referred to as a hydraulic pump. The pump creates a flow of fluid (paint) and, because of the restriction of the hose and the spray gun, the paint is pressurized. This type spray system eliminates evaporation of the volatile substances of the mixture before striking the surface since the mixture contains no air. The absence of air in the paint mixture also reduces the tendency of paint particles to mix with the surrounding atmosphere. This permits painting in more confined spaces with less fumes as it reduces the hazards of asphyxiation and fire.

The compressed air for this unit may be supplied by air compressors similar to those used with the airmix systems. Air pressures used to operate this unit may vary from 40 to 120 psi with actual delivery of approximately 4

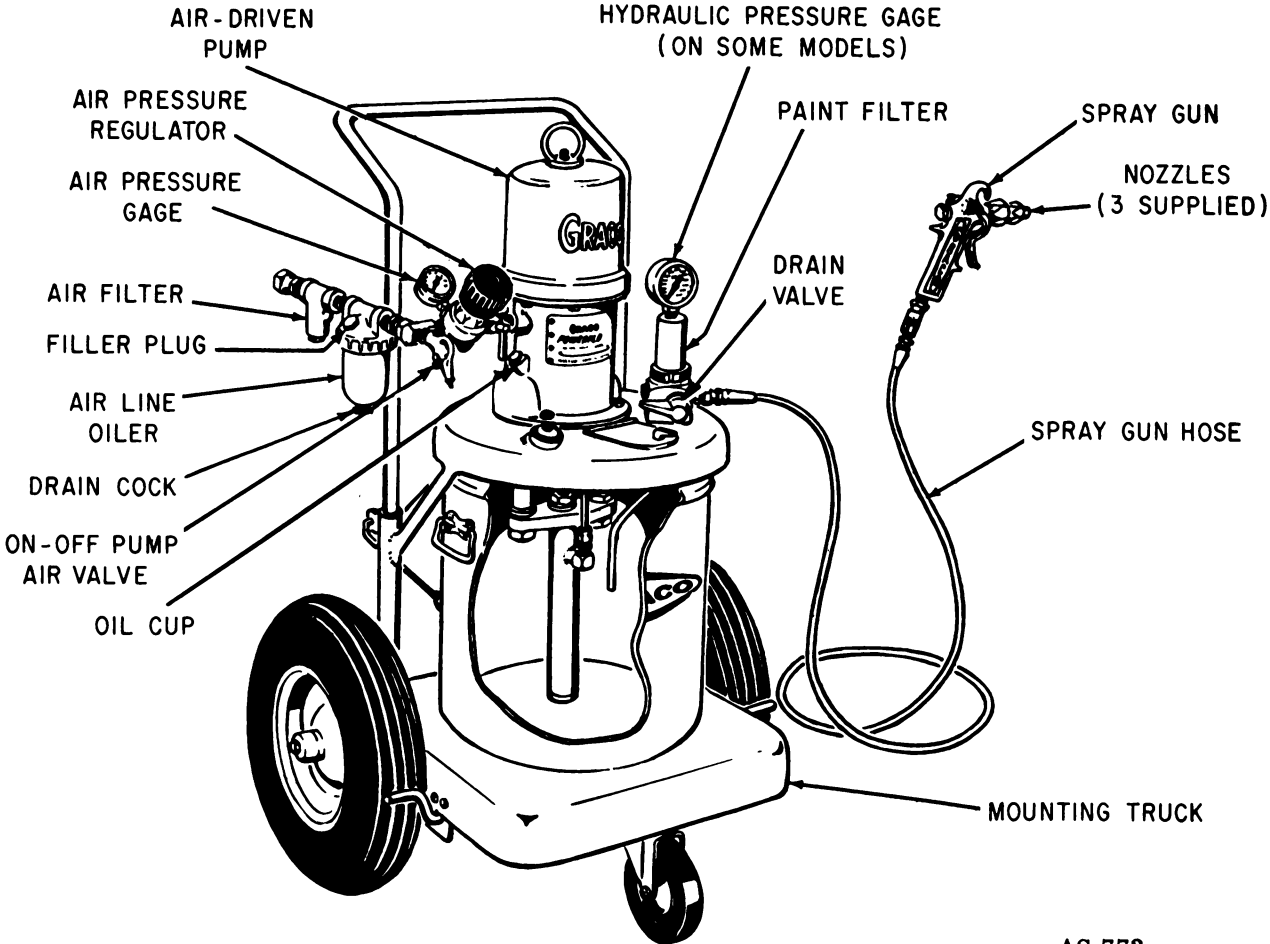


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Figure 17-20.—Airless paint spray unit.

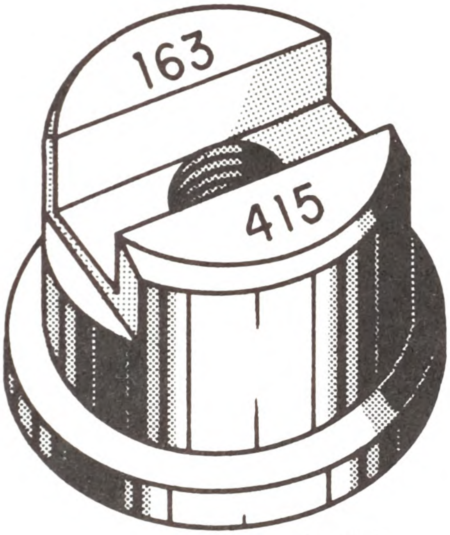

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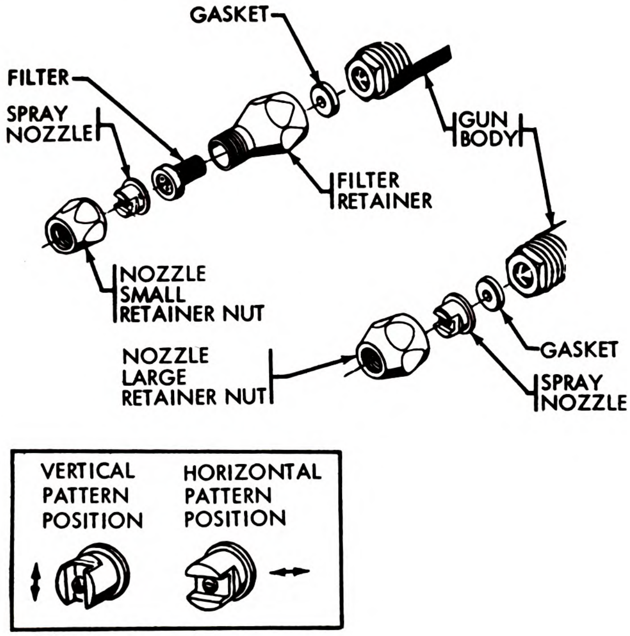
Figure 17-21.—Spray gun nozzle—airless spray unit.



AS.774
Figure 17-22.—Spray gun nozzle assembly—airless spray unit.

cubic feet per minute (cfm) of air volume required to operate the pump air motor, for each spray gun that is in continuous use. The air consumption (cfm) varies with the pump pressure and size of nozzle required to produce the desired breakup and spray pattern of the paint.

The major components used for the control of this unit are described in the following paragraphs. The appropriate technical manual must be consulted for the inspection interval and maintenance of these components.

Air Filter

The compressed air flows from the supply source through the air supply line and enters the air filter. The air filter contains a replaceable monel screen mesh element which removes dirt and other foreign matter before the air enters the unit. The element must be removed at frequent intervals for cleaning and inspection.

Air Line Oiler

After the air flows through the filter, it enters the oiler. The major parts of the oiler are the head, which contains the air passage; a plastic bowl, which provides a reservoir for the oil; and an element, which contains a feeder wick. The feeder wick extends from the reservoir of oil to the air passage. As the air flows through the passage, a fine oil mist enters the air and serves as a lubricant for the air motor. The oiler automatically varies the oil mist delivery with airflow variations. The oiler feeder wick is preset (adjusted) at the factory so that it should provide sufficient oil for lubrication of the air motor. Should it become necessary to adjust the feeder wick, follow the procedures listed in the appropriate technical manual.

The oil supply should be checked daily and replenished as often as necessary with a light grade of oil. A filler plug is located at the top of the head for this purpose. As shown in figure 17-20, a drain cock is provided on the bottom of the bowl. This provides a means whereby any sediment that collects in the bowl can be drained off. The oiler should be drained and the plastic bowl cleaned as often as necessary.

Air Pressure Gage

The air pressure gage indicates the pressure of air being used to power the pump. The

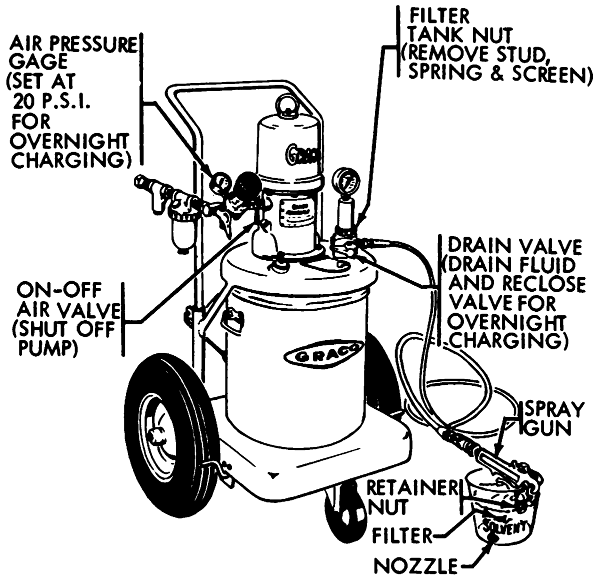


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Figure 17-23.—Cleaning airless paint spray unit.

indicator hand will remain at its dial reading until the air supply is turned off and pressure in the supply line is relieved. If the pointer does not show pressure, the unit must be stopped immediately and the cause determined.

Air Pressure Regulator

The pressure regulator controls the pump power stroke speed in direct proportion to the pressure requirements at the spray gun nozzle. To start the pump and increase its speed, the knob of the regulator is turned clockwise which admits and increases the supply of air pressure to the pump.

CAUTION: Do not adjust the air regulator to a pressure higher than 120 psi.

Pump ON-OFF Air Control Valve

This is a manual control for admitting air or shutting off air to the pump. This valve must be fully open when operating the pump and not used partially open to regulate the speed of the pump.

Air-Driven Pump

As previously stated, the air pressure supplies the power for the pump. The pump is of the hydraulic, reciprocating type and pumps the paint from the container through the hose to the spray gun. The ratio of paint pressure to air pressure is approximately 28 to 1. For example, an air pressure of 50 psi produces a paint pressure of approximately 1,400 psi.

The throat bearing in the air motor base of the pump must be lubricated periodically. An oilcup, located just below the air inlet opening to the pump (fig. 17-20), is provided for this purpose. The oilcup should be filled with a light grade oil as required.

CAUTION: The pump must be grounded to prevent static sparking. One means of effectively grounding the pump is to use a static wire air supply hose. Also, the compressor must be grounded for continuity.

Paint (Hydraulic) Pressure Gage

This gage indicates the pressure developed by the pump. When the pump is operating normally or when the gun is closed and the pump is under pressure, the indicator hand will show the pressure developed, which should be approximately 28 times the reading of the air pressure gage. When the pump is not in operation and the pump pressure is relieved, the hand will drop to the zero reading on the dial. If the hand registers continuously too low a pump pressure, a leak in the high-pressure paint system is indicated. The leak may be in the pump check valves, the spray gun hose, or the connections. If the hand registers continuously too high, it is an indication that the air pressure is too high and should be reduced accordingly.

Paint Filter

The paint filter is similar to the air filter. The element is a replaceable mesh screen and removes dirt and foreign matter from the paint as it flows from the container. This element must be removed and cleaned or replaced periodically.

Paint Filter Drain Valve

This valve provides a method for mixing the paint before spraying. With the valve in the

open position (valve handle in the vertical position), the paint is circulated through the filter and back into the supply container. The valve must be closed (valve handle in the horizontal position) when the unit is spraying so that the paint will not bypass into the supply container.

Spray Gun

The spray gun is supplied with three control nozzles. The nozzles, which are of different size orifices and fan widths, are used to control the paint spray patterns. The correct type and size of nozzle vary with the type of paint and the pump pressure required for spraying.

The part number is stamped on the front of each nozzle. For example, the part number of the nozzle illustrated in figure 17-21 is 163-415. The last three digits of the number identify the fan width and the orifice size of the nozzle. The first digit of the last three, when doubled, gives the minimum fan width in inches (add two inches for maximum fan width). The last two digits give the orifice size in thousandths of an inch. For example, the nozzle illustrated in figure 17-21 provides an 8- to 10-inch fan width and a 0.015-inch orifice. The part numbers of the other two nozzles are: 163-313 (6- to 8-inch fan width and 0.013-inch orifice) and 163-617 (12- to 14-inch fan width and 0.017-inch orifice).

Figure 17-22 shows an exploded view of the spray gun nozzle assembly. To install the nozzle, remove the nozzle retainer nut from the gun filter retainer. Place the desired nozzle in the nut and replace the nut. Tighten the nut with moderate tension only. Do not overtighten. The nozzle may be set for vertical or horizontal spray patterns with a special wrench supplied with the unit. The large retainer nut is provided with the unit. This nut is used when installing a nozzle without the gun filter.

The exposed portion of the spray gun trigger shaft should be lubricated frequently. At the completion of each day's spraying the nozzle and gun filter must be removed and soaked in a clean, compatible solvent. They must then be scrubbed with brushes which are supplied with the unit.

Spraying Technique

The spray pattern is adjusted with the air pressure regulator. After starting the unit, adjust the regulator until the pump develops the minimum pressure required for the desired paint breakup and spray pattern. To increase the pressure, turn the air regulator control knob clockwise, and to decrease pressure, turn the control knob counterclockwise.

Having established the paint breakup and spray pattern for the desired coat application, the spray gun may be triggered and released without repeated manipulation of the pressure controls. The paint pressure is contained in the system ready for instantaneous release whenever the gun is triggered to the open position. Good airless spraying is very similar to the air-mix spraying, except in the following ways:

1. The gun should be held so the nozzle is 10 to 12 inches from the spraying surface. This distance may be greater if the spray will cover satisfactorily.
2. Gun triggering action should be quick, full and positive when opening or closing the gun. Whenever possible, trigger the gun open at the beginning of the pass before meeting the work and release trigger at the end of the pass after pattern has left the work. Trigger tension is preset for comfortable trigger action and needs no adjustments.
3. Less pattern overlapping is necessary due to the heavier coating thickness produced with the airless spraying process.

The appropriate technical manual should be consulted for assistance in locating troubles which may occur during spraying.

CAUTION: Spray gun nozzle velocity is dangerous. This spray gun must be handled as cautiously as any gun—loaded or unloaded. Do not point spray gun at anyone. At close range the paint pressure released from the nozzle can put out eyes, penetrate the skin, or cause other injuries. Never attempt to unclog a nozzle while it is installed in the gun, and be sure to relieve pump pressure before removing nozzle or filter for service.

Shutdown Cleaning

The airless spray unit must be cleaned at the completion of each day's spraying. The prescribed cleaning procedure is described in the following steps. (Refer to fig. 17-23.)

1. Reduce to 20 psi the air pressure to the pump by unscrewing the air regulator control knob one turn at a time and triggering the gun open each time to bleed higher air pressure from the regulator.

2. With the air pressure reduced to 20 psi and the pump operating, stop the operation of the pump by closing the ON-OFF air control valve.

3. Open filter drain valve to relieve paint pressure in the system and drain paint from the filter. After draining stops, close drain valve.

4. Unscrew filter tank nut. Remove the filter stud, spring, and screen element. Brush the paint thoroughly from the parts with clean compatible solvent. Then dry the parts with compressed air and reinstall.

5. Remove the nozzle and filter from the gun, and replace nozzle retainer nut. Clean gun, nozzle, and filter with clean solvent. Leave the nozzle and filter in solvent overnight. Also keep the forward end of the gun in solvent overnight.

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